DUALSPHYSICS: APPLICATIONS IN RENEWABLE ENERGY

3RD IBERIAN SPH - OURENSE 2024

This presentation resumes the work of many researchers and institutions in developing and applying DualSPHysics for renewable energy simulations.

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CONTENTS

INTRODUCTION

TOPIC

CHALLENGES

STRATEGY

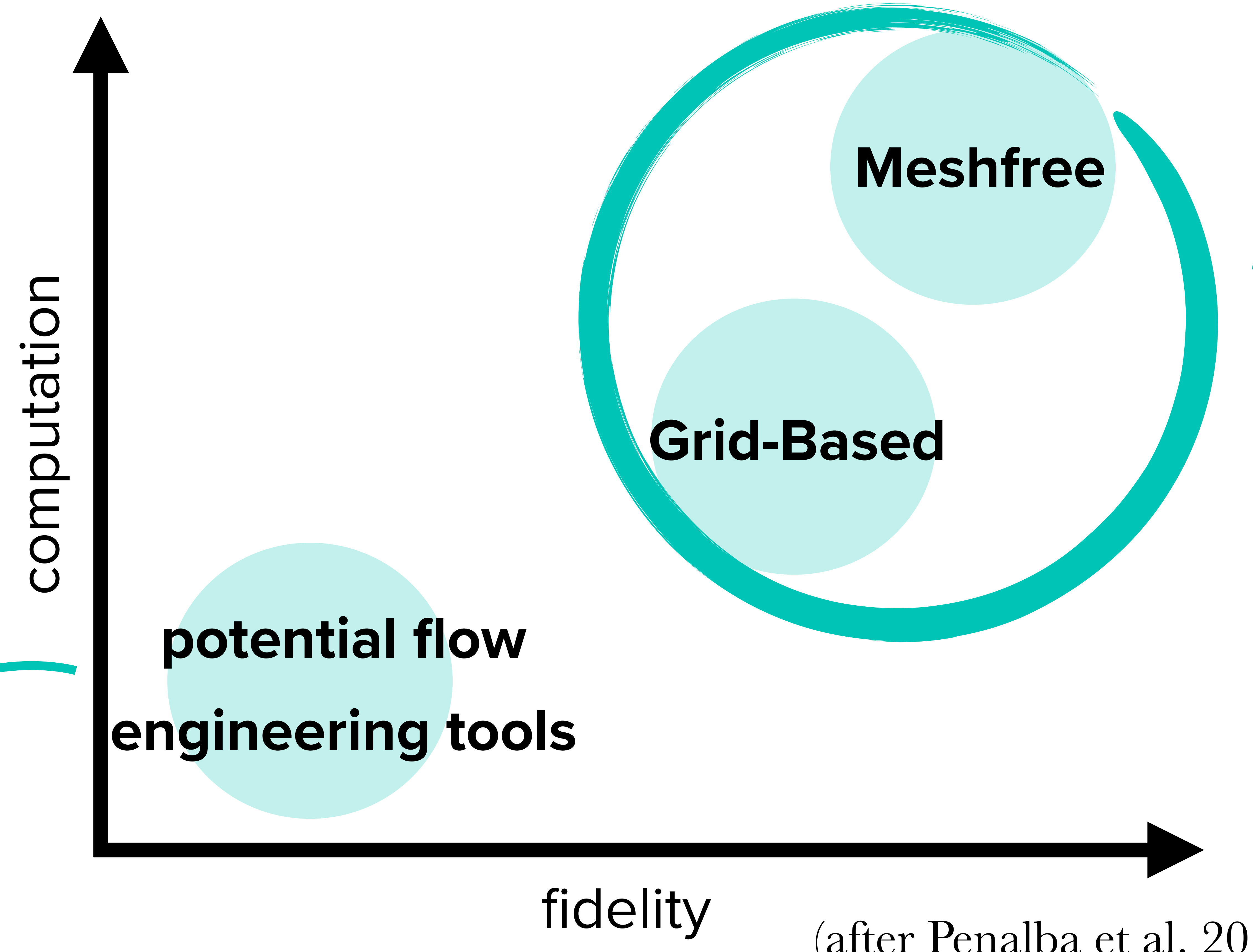
TOPIC

Offshore renewable energy (ORE) and numerical modeling

Usually...

- ✗ Multi-body systems
  Non-linear responses
- ✓ PTO optimization
  Power output estimation

Performance evaluation in operational conditions, design guidelines compliance



(after Penalba et al. 2017)

ORE simulations

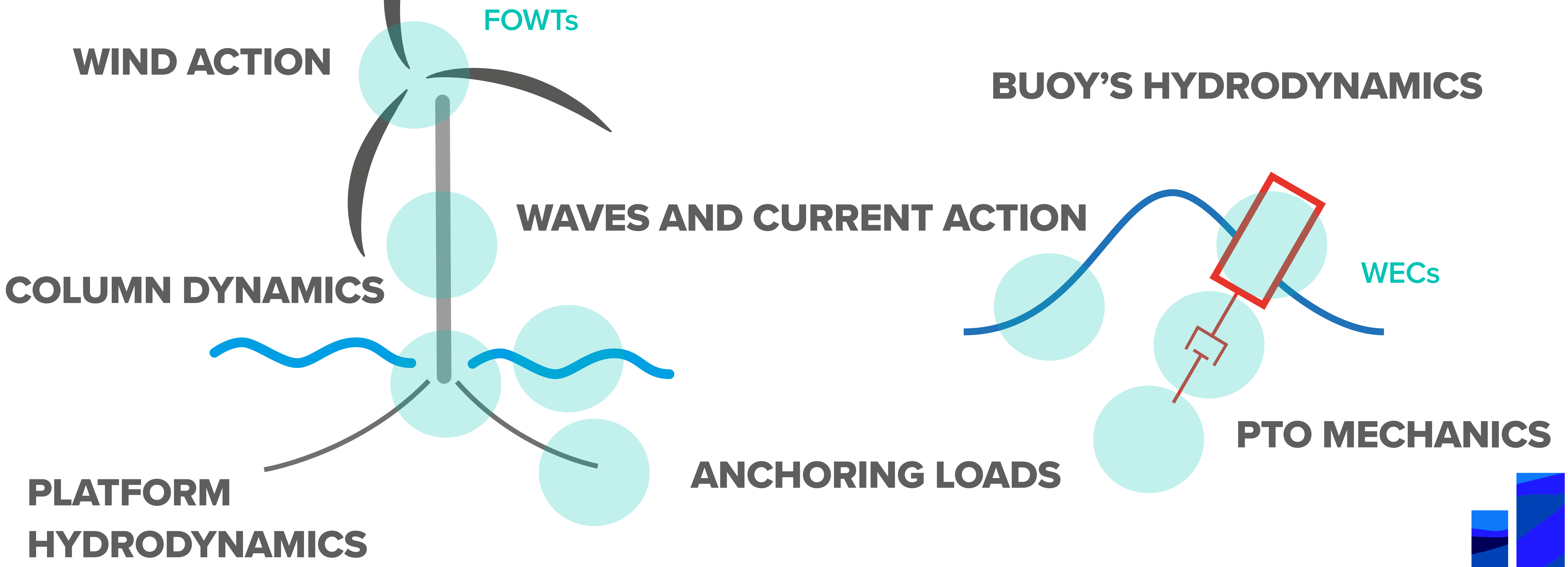
Extreme events, survivability analysis

Usually...

- ✗ Performance
  Early design stages
- ✓ Complex systems and hydrodynamics
  Large displacements

CHALLENGES Actual complexity of offshore systems

risk of failure (high capital costs)
power production inconsistencies
responses in extreme and harsh environments



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STRATEGY Include CFD in the design process?

State of the art of CFD models:

- Rapidly increasing computational power
- Reliable models
- Really cost-effective

→ **FORESEE WIDER APPLICATIONS FOR HIGH-FIDELITY CODES:**

"EXTREME" ↔ **"COMPLEX"**

nonlinear structure response
nonlinear hydrodynamic
second order effects

COMPREHENSIVE AND EFFICIENT DESIGN

SURVIVABILITY — Harsh sea states, tsunami waves…

but also

OPERATIONAL CONDITIONS — Wave-current combinations, irregular wave trains

cpu gpu DualSPHysics

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METHODS

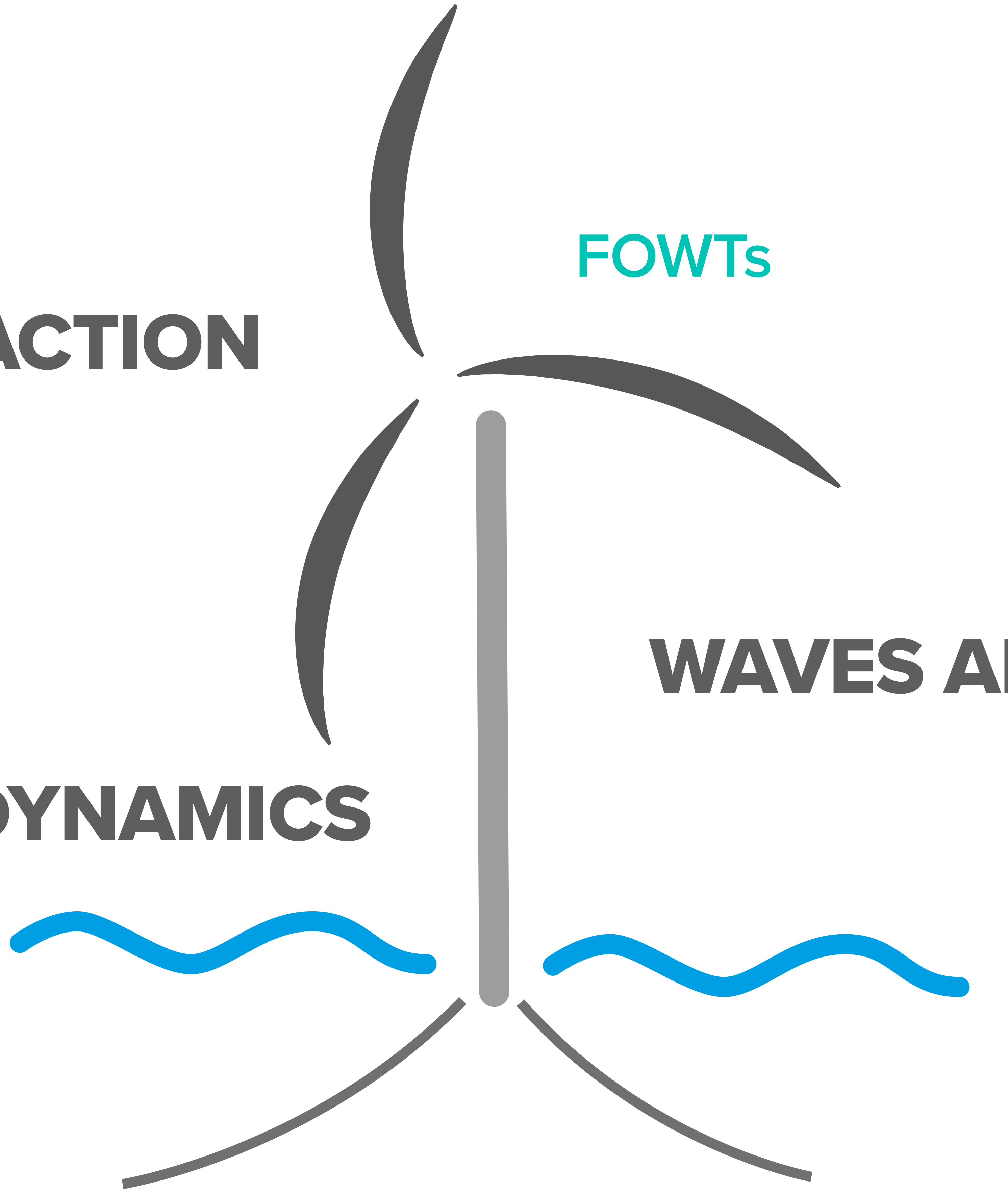
FRAMEWORK CAPABILITIES

PROJECT CHRONO

MOORDYN+

WAVE FLUMES

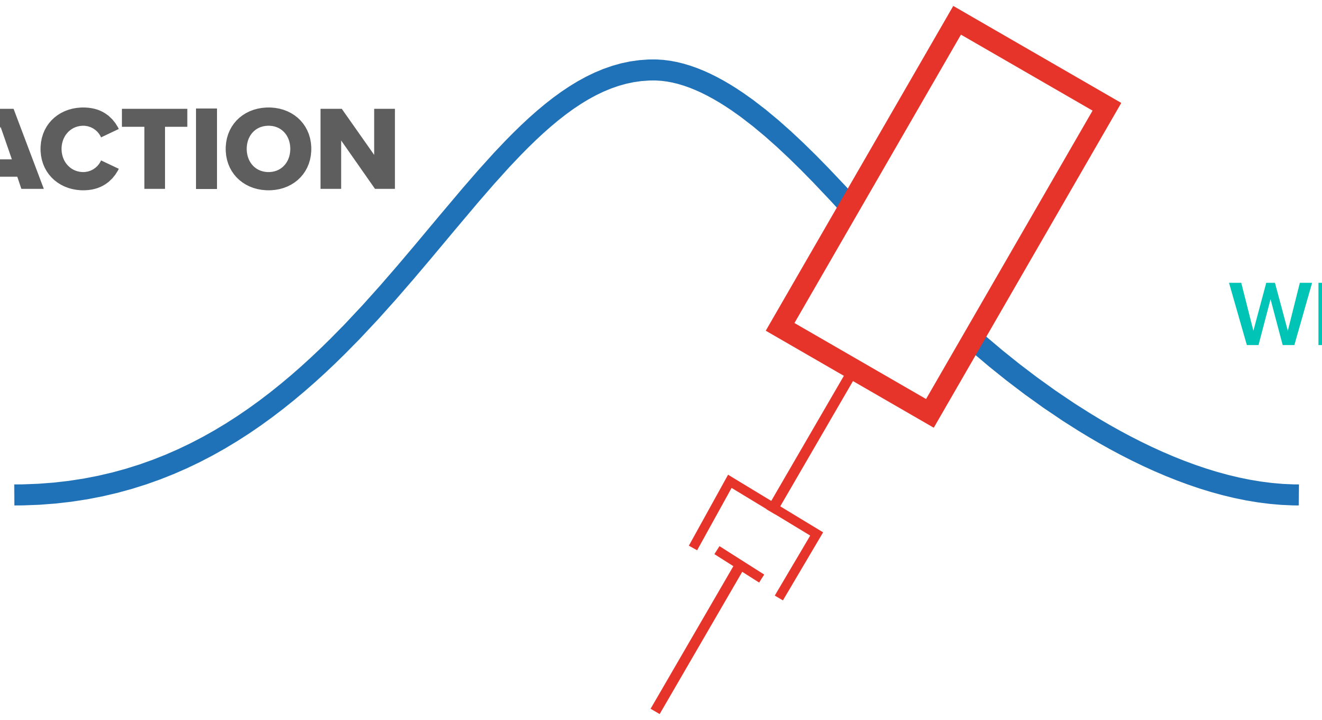
FRAMEWORK CAPABILITIES complexity → tools



WIND ACTION

BUOY'S HYDRODYNAMICS

WAVES AND CURRENT ACTION



COLUMN DYNAMICS

ANCHORING LOADS

PTO MECHANICS

PLATFORM HYDRODYNAMICS

FRAMEWORK CAPABILITIES complexity → tools

WIND ACTION

COLUMN DYNAMICS

PTO MECHANICS

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WAVES AND CURRENT ACTION

PROJECT CHRONO

cpu gpu DualSPHysics

ANCHORING LOADS

Mooring Dynamics MoorDyn+

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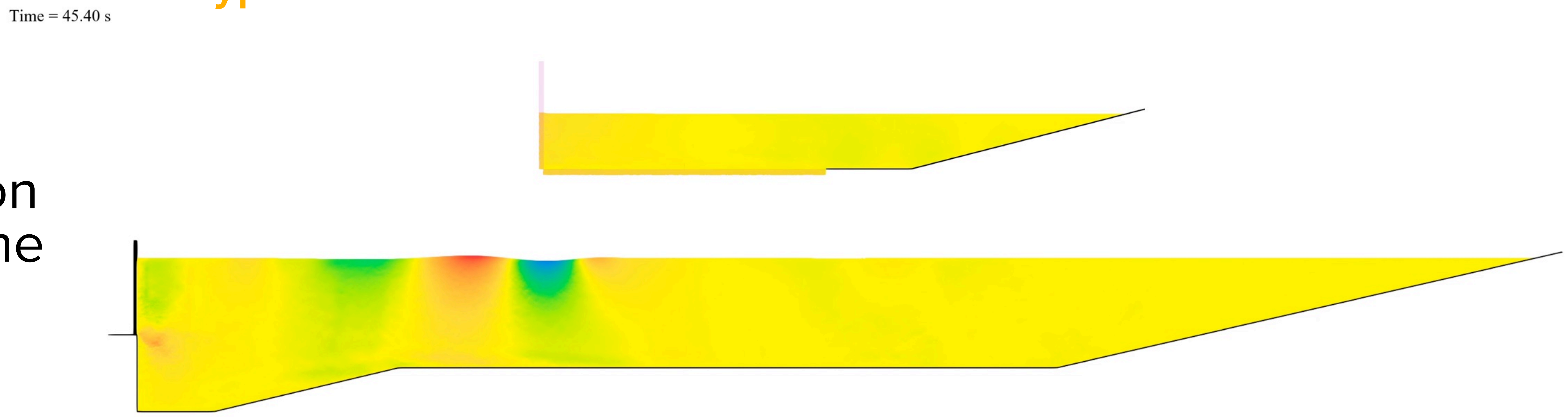
METHODS

WAVE FLUMES

SPH guarantees the flexibility for supporting wave-structure interaction including wave-breaking and extreme deformations

Focused or irregular waves generation

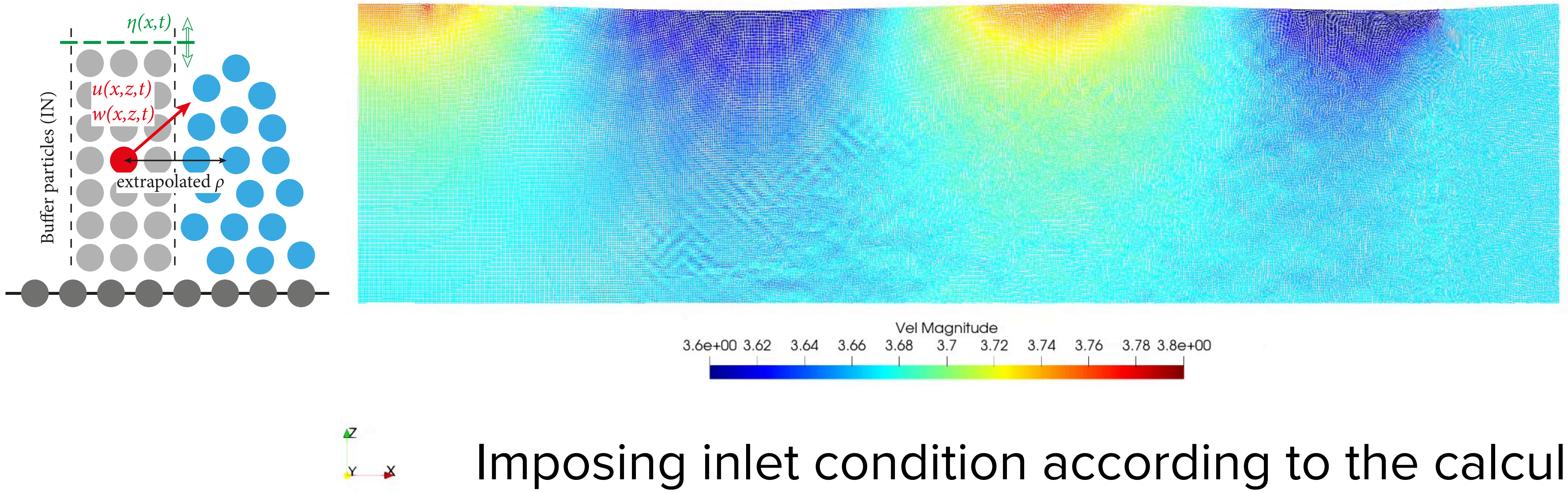
Piston-type wavemaker

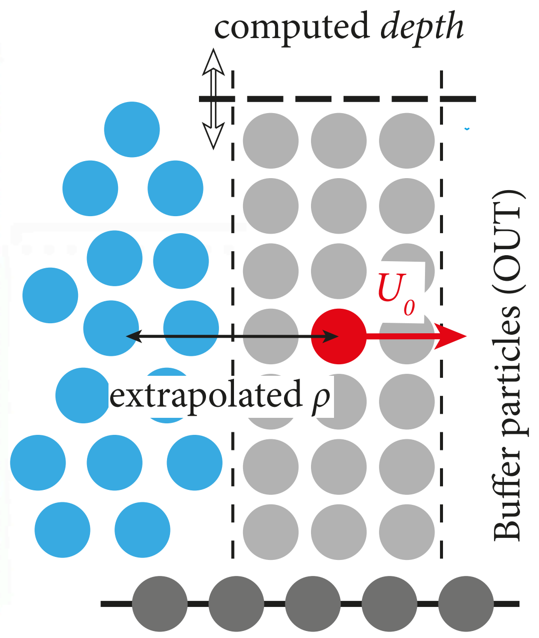


NewWave theory implemented in version 5.2

Waves and current generation

Open Boundaries + Absorption Zone





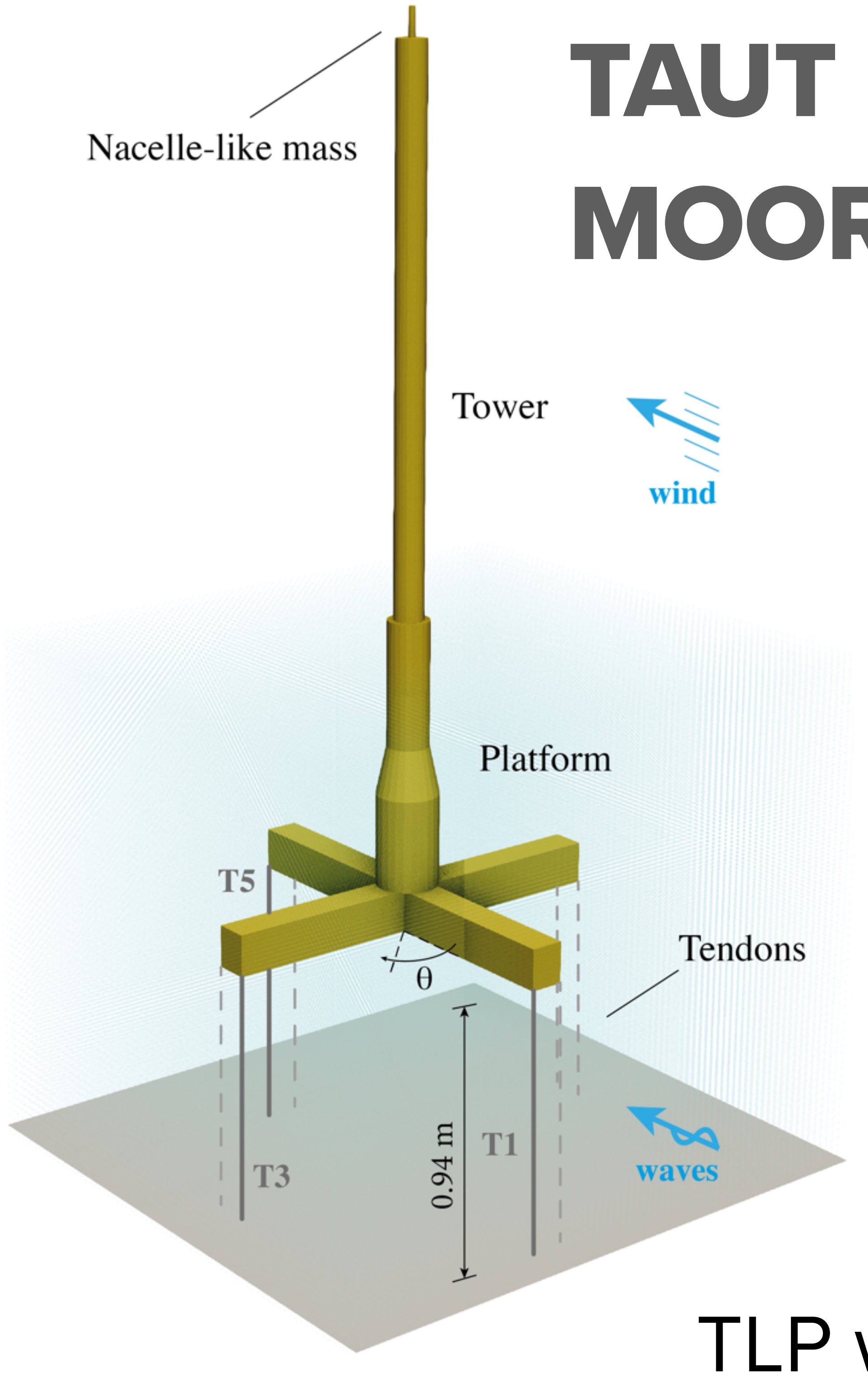
Imposing inlet condition according to the calculated flow velocity field

PROJECT CHRONO

Open source multiphysics library

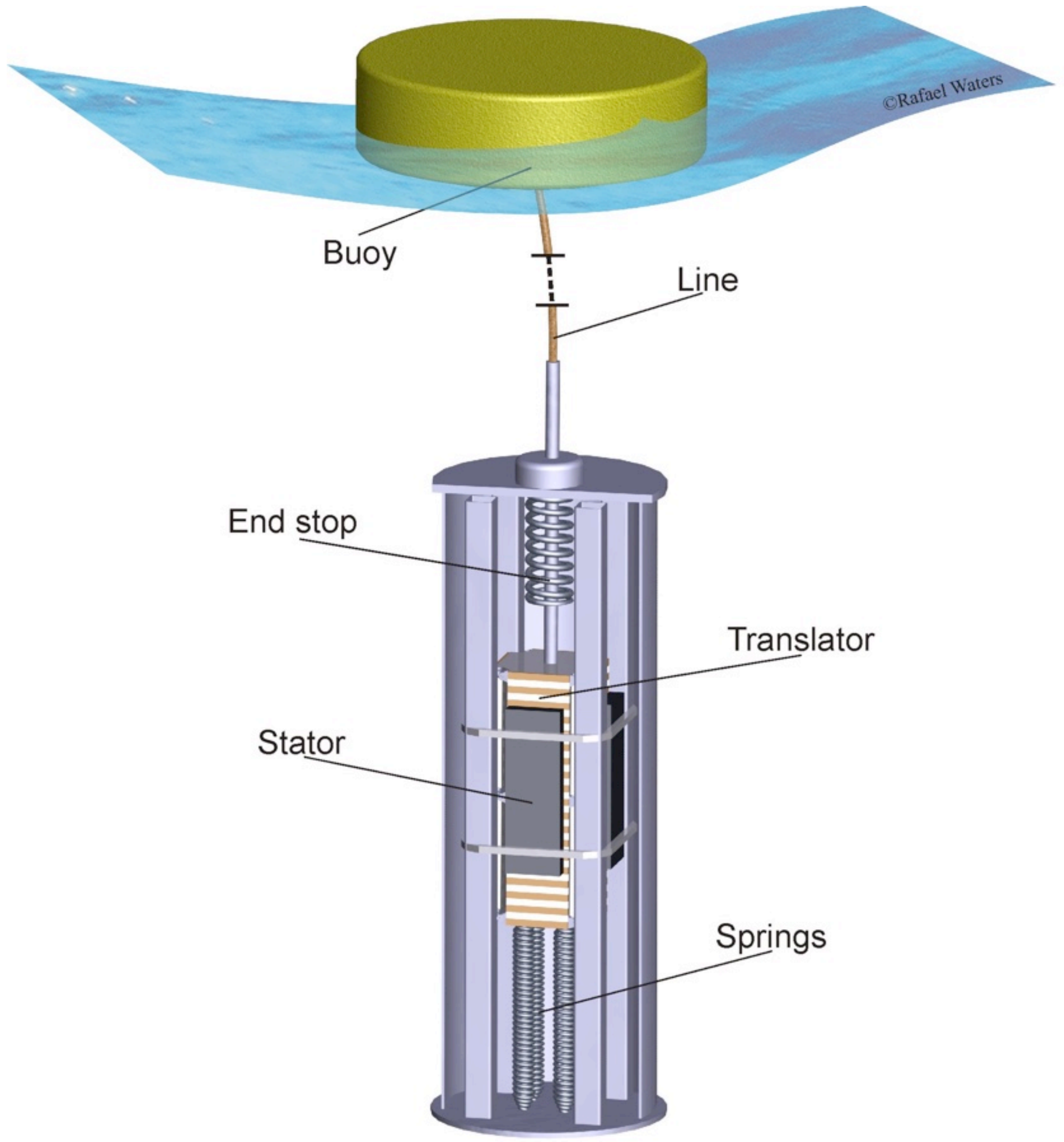
- multi-body support
- smooth and non-smooth contacts
- kinematic and dynamic restrictions

TAUT MOORINGS



TLP with 8 tendons

PTO SYSTEMS



Point-absorber WEC

Martínez-Estévez et al., 2023, **CPC**

DualSPHysics — Compute fluid forces

DSPHChronoLib — exchange information

PROJECT CHRONO — Apply constraints and contact forces

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MOORDYN+

Anchoring system solver

Based upon the original implementation “Moordyn”

This lumped mass mooring line model is able to account for:

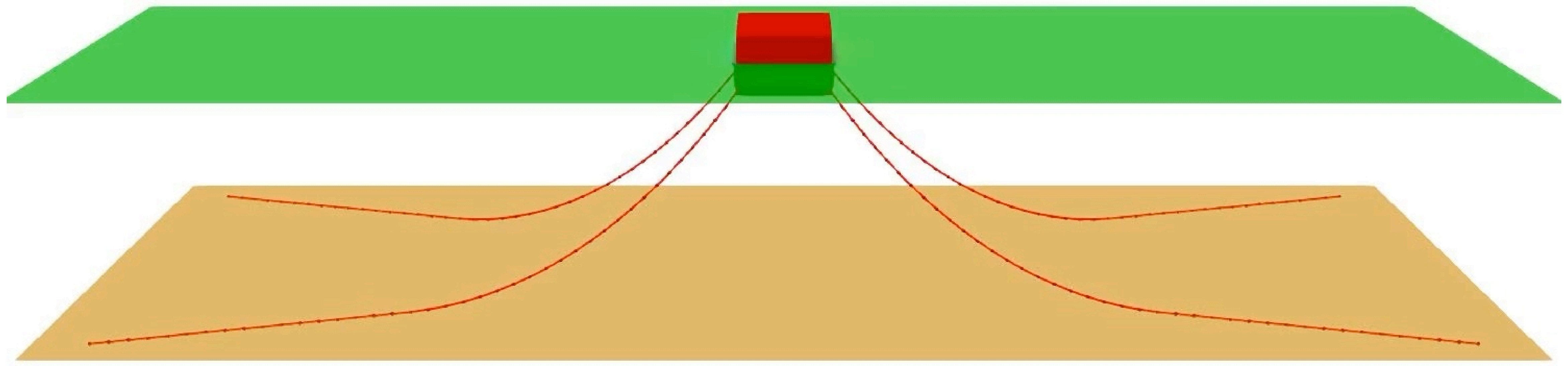
- account for axial stiffness
- damping
- weight and buoyancy forces
- vertical spring-damper forces due to the friction with the seabed

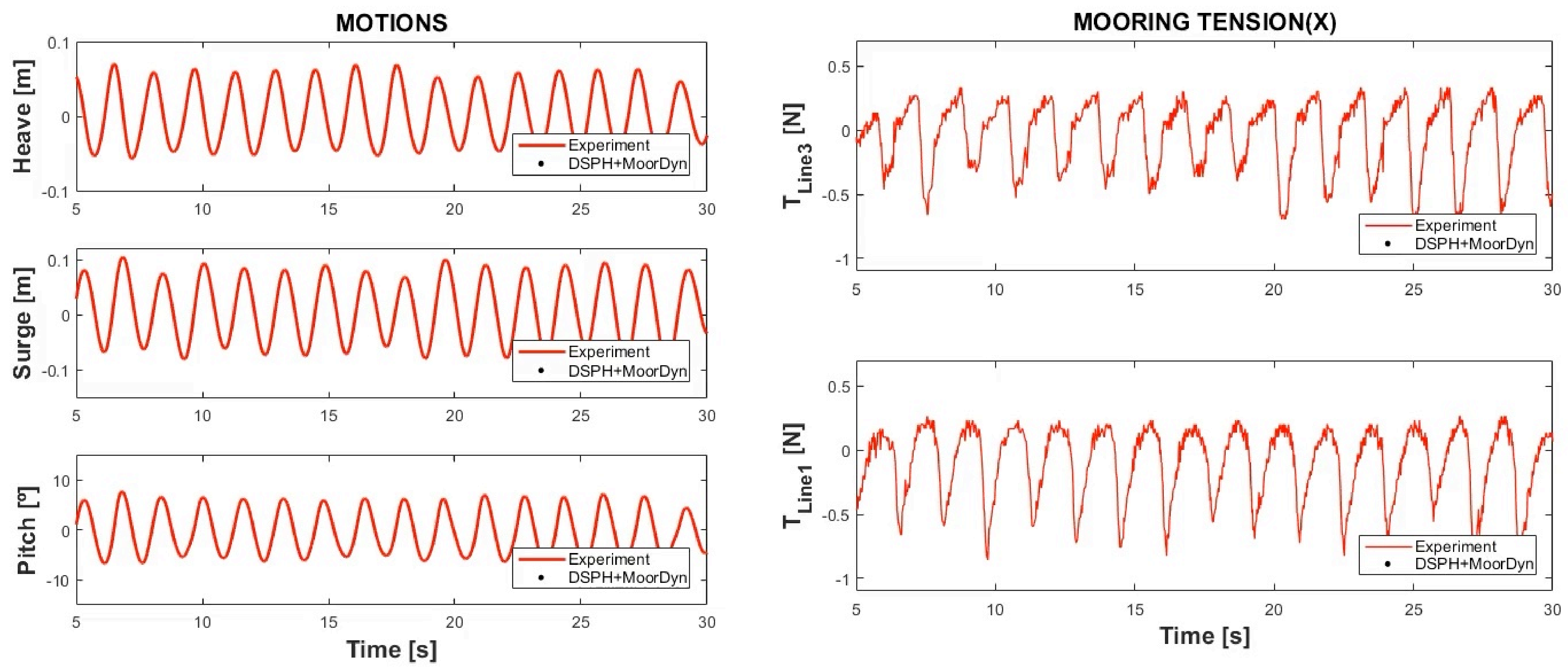
+

- solve interconnected floating bodies
- to assign different depths for catenary-like connections.

Floating moored BOX
Regular waves; H=0.12 m, T=1.6s, d=0.5m

Time: 0.02 s





REVIEW OF APPLICATIONS

WAVE ENERGY

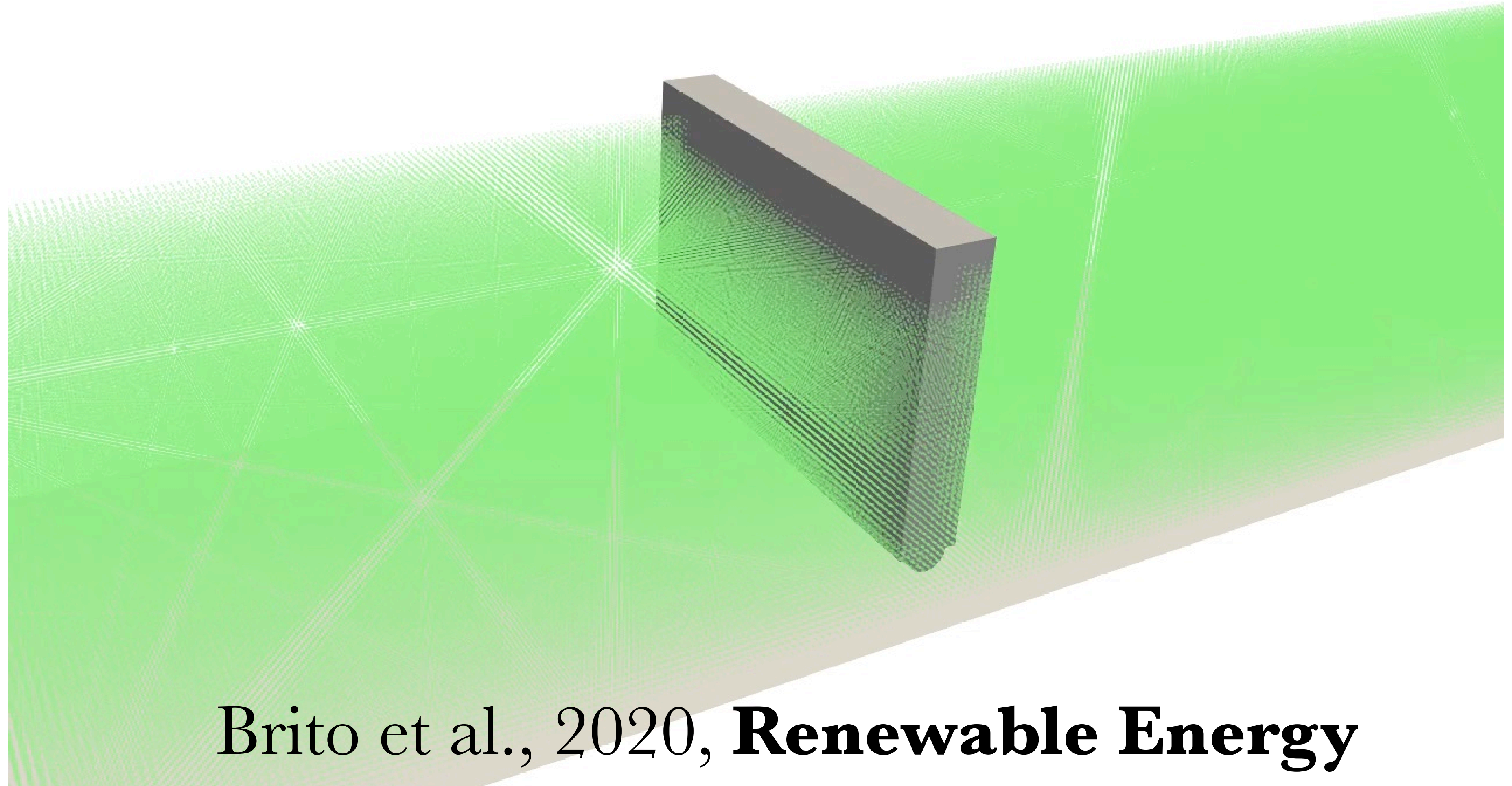
WIND ENERGY

HYBRID PLATFORMS

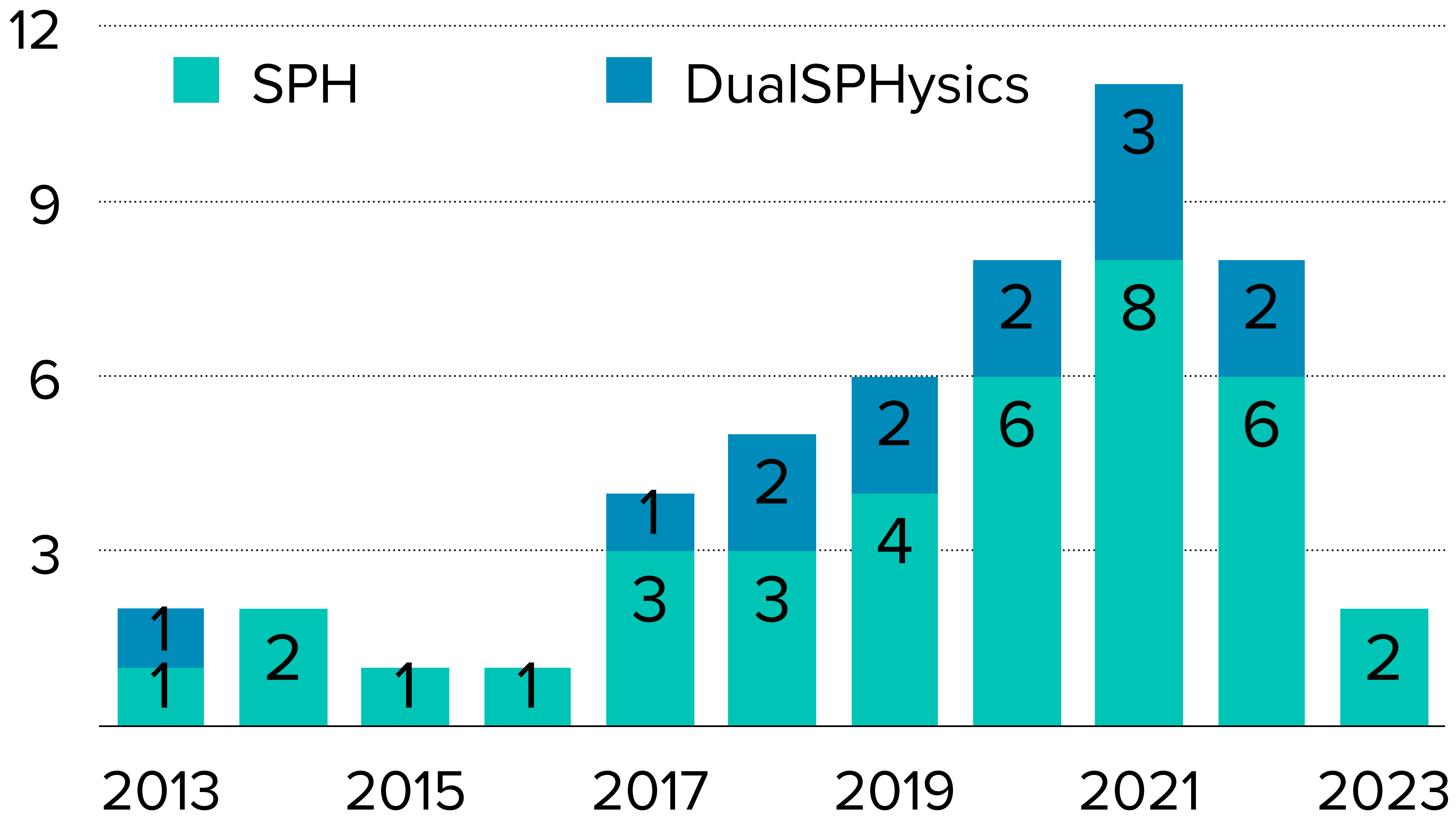
REVIEW OF APPLICATIONS

WAVE ENERGY

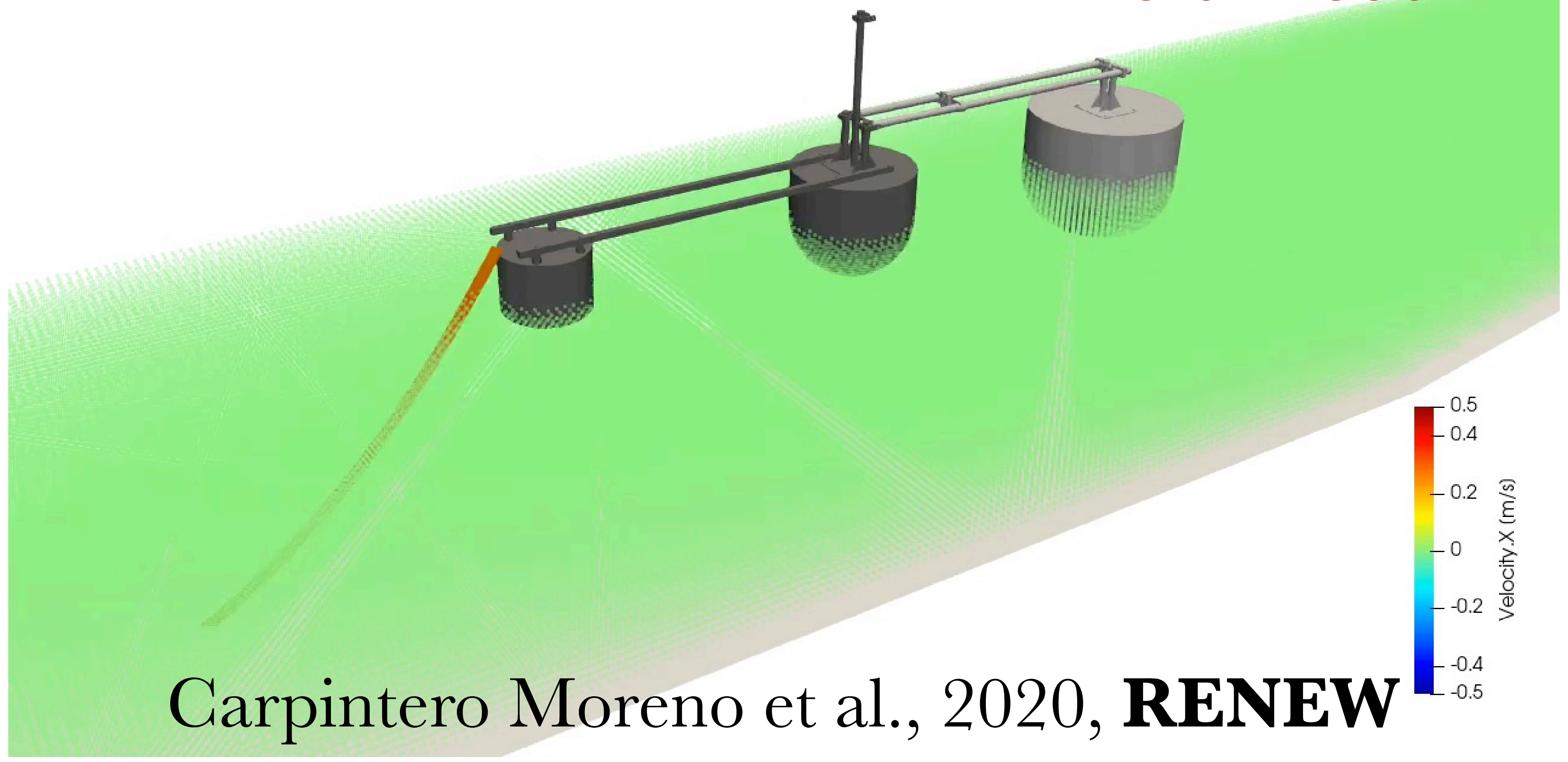
OWSC



Brito et al., 2020, **Renewable Energy**

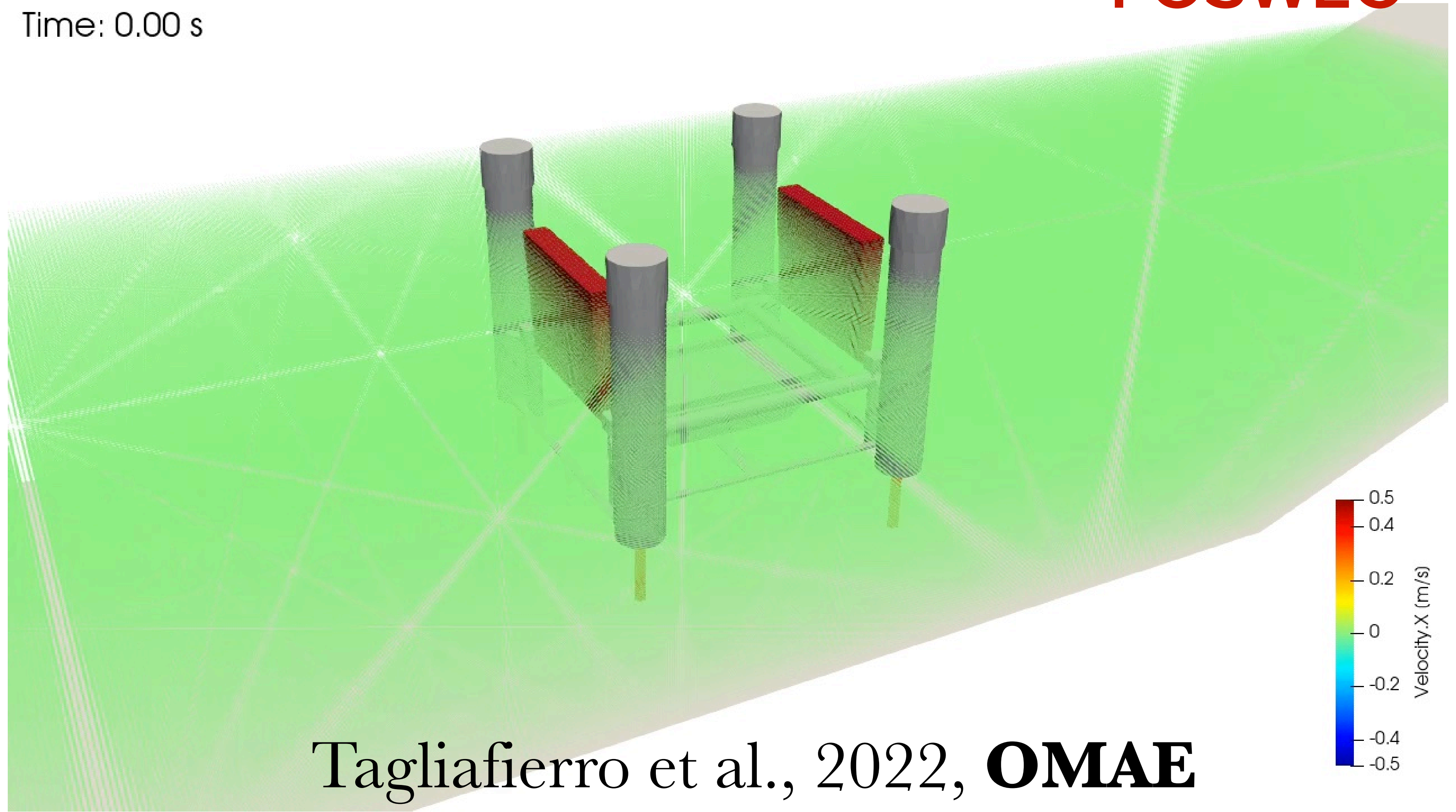


Multi-Float M4



Carpintero Moreno et al., 2020, **RENEW**

FOSWEC



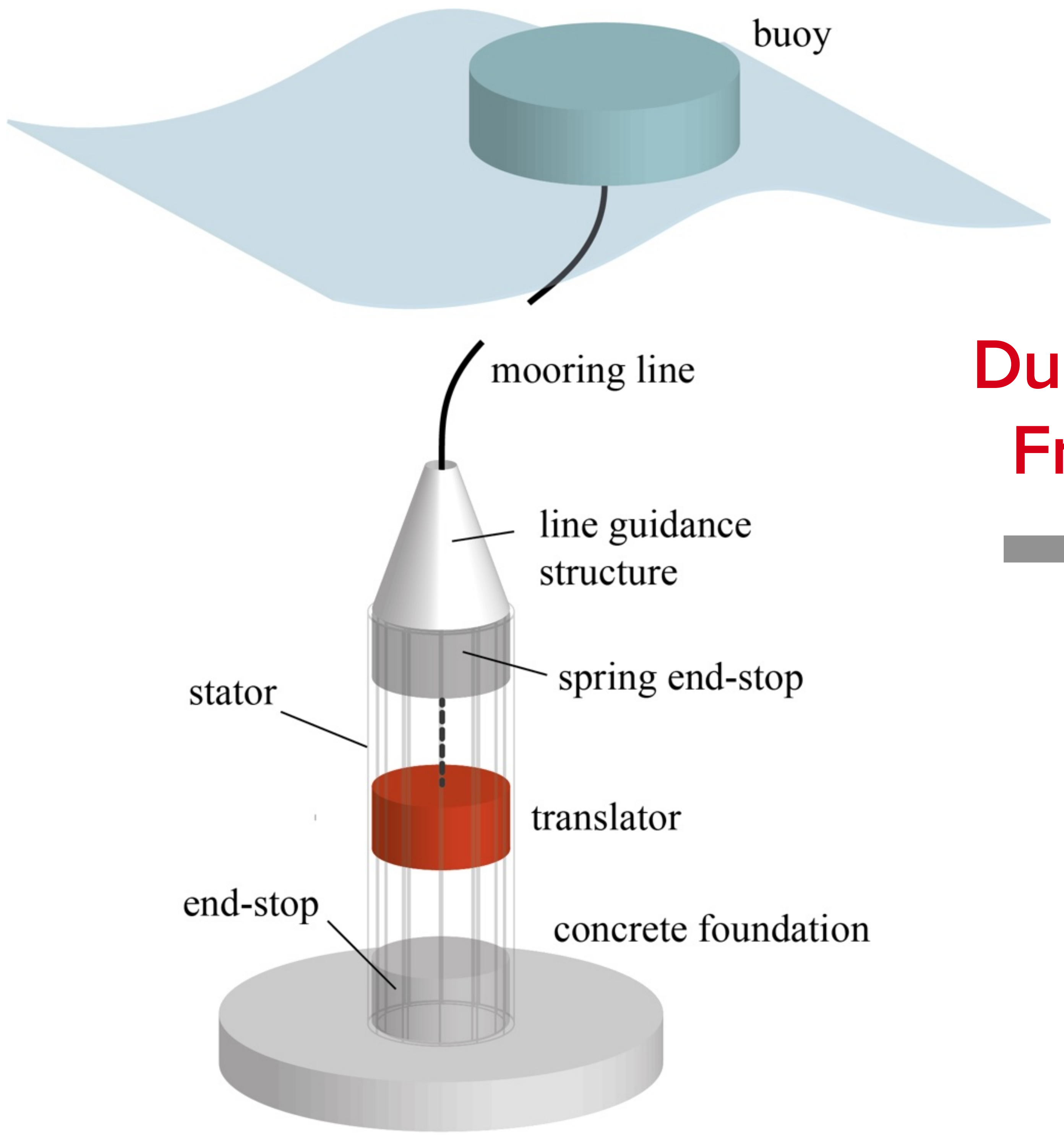
Tagliafierro et al., 2022, **OMAE**

WAVE ENERGY

Uppsala University WEC (UUWEC)

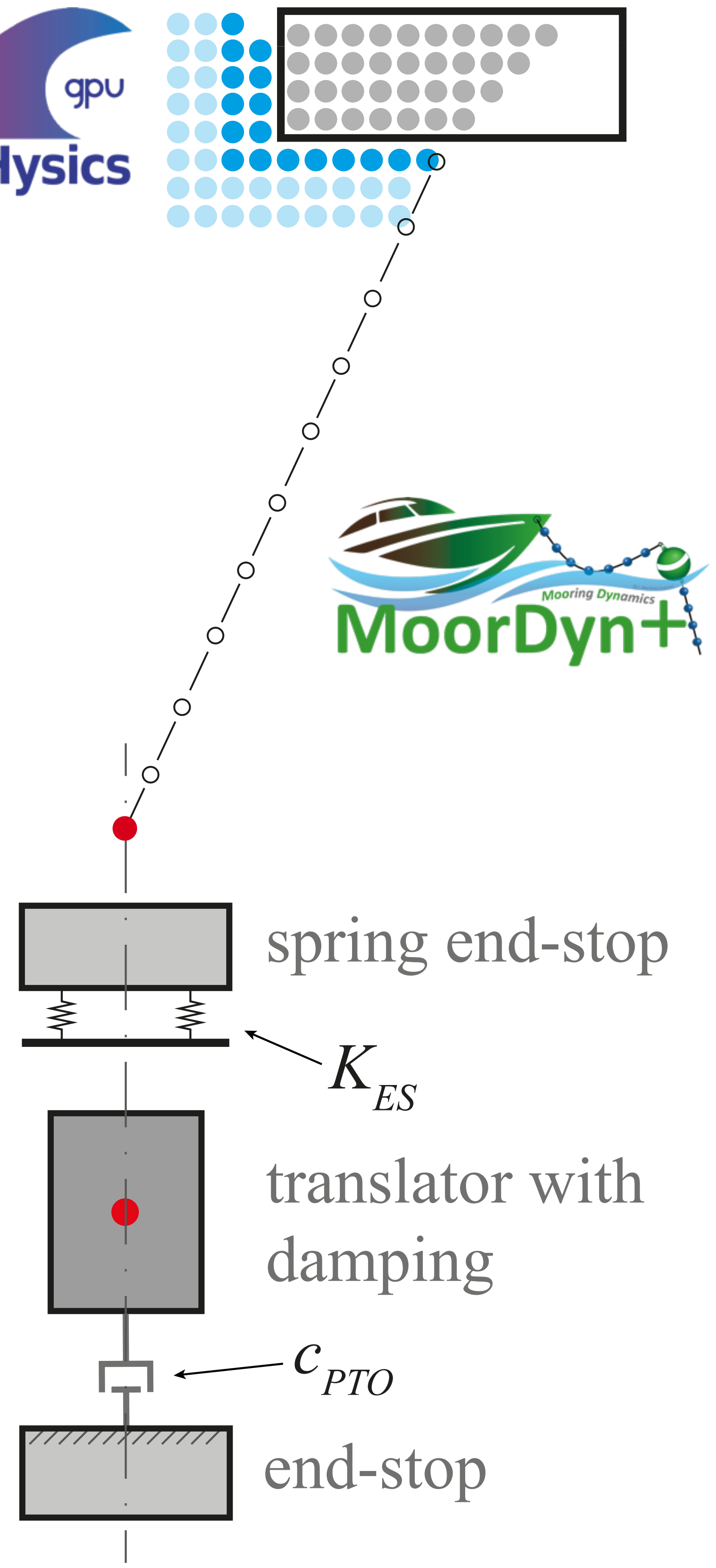
UPPSALA UNIVERSITET

Taut-moored point-absorber equipped with a linear magnetic generator - experimental data available for embedded focused waves



Göteman et al., 2015, **ISOPE**

DualSPHysics Framework



"COMPLEX" ENVIRONMENTAL CONDITIONS

SURVIVABILITY

Response under focused waves

Tagliafierro et al., 2022, **APEN**

OPERATIONAL CONDITIONS

Response in waves and current fields

Capasso et al., 2024, **OMAE** (u.r.)

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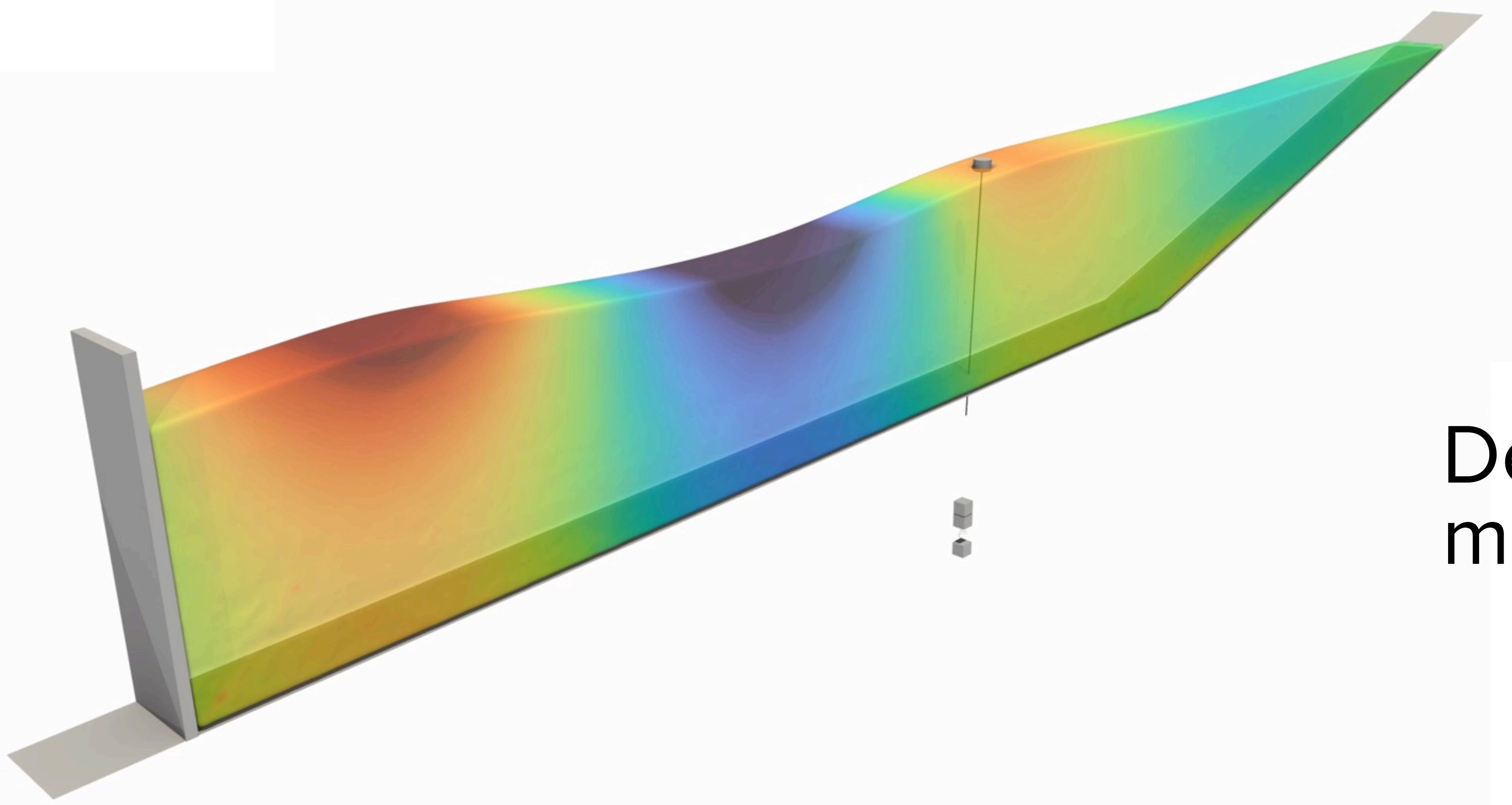
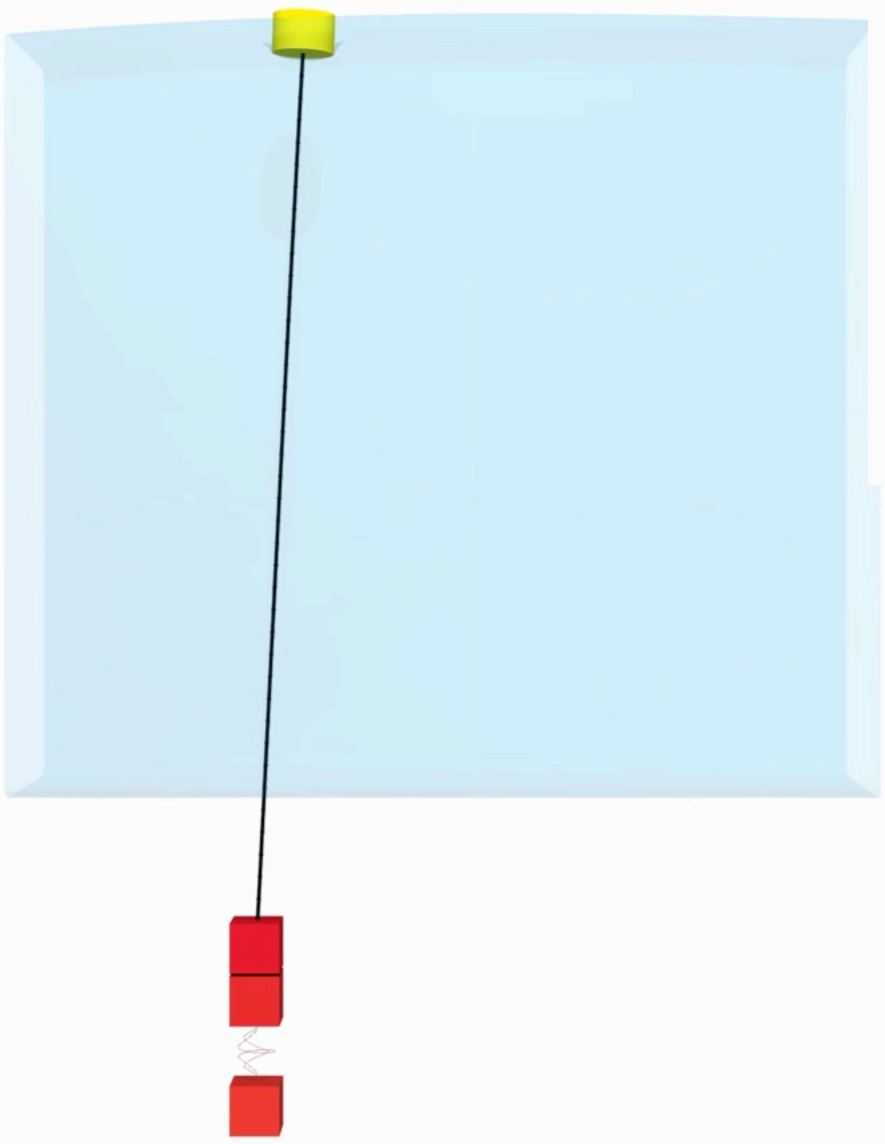
WAVE ENERGY

UUWEC: focused wave validation

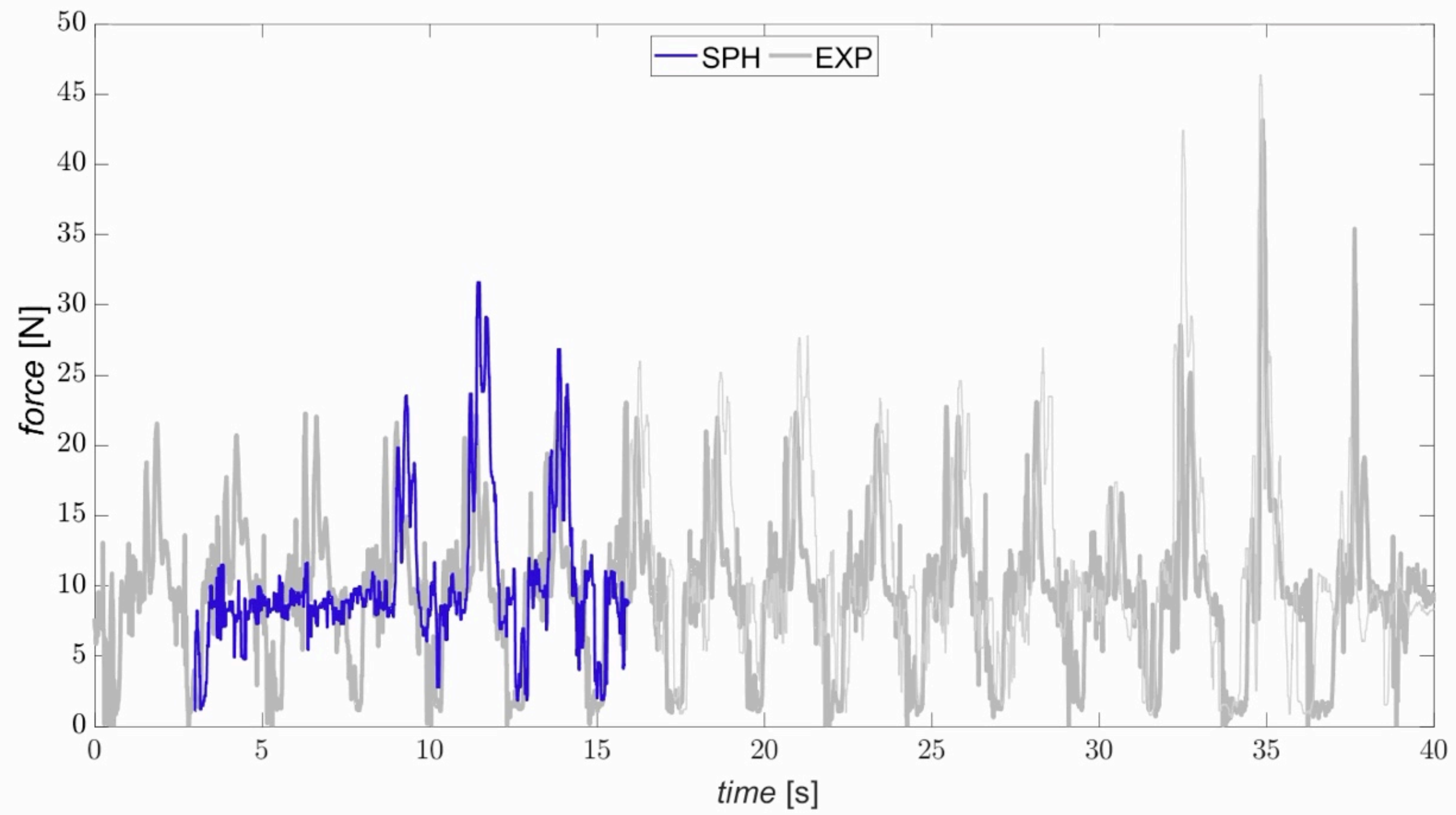
SURVIVABILITY

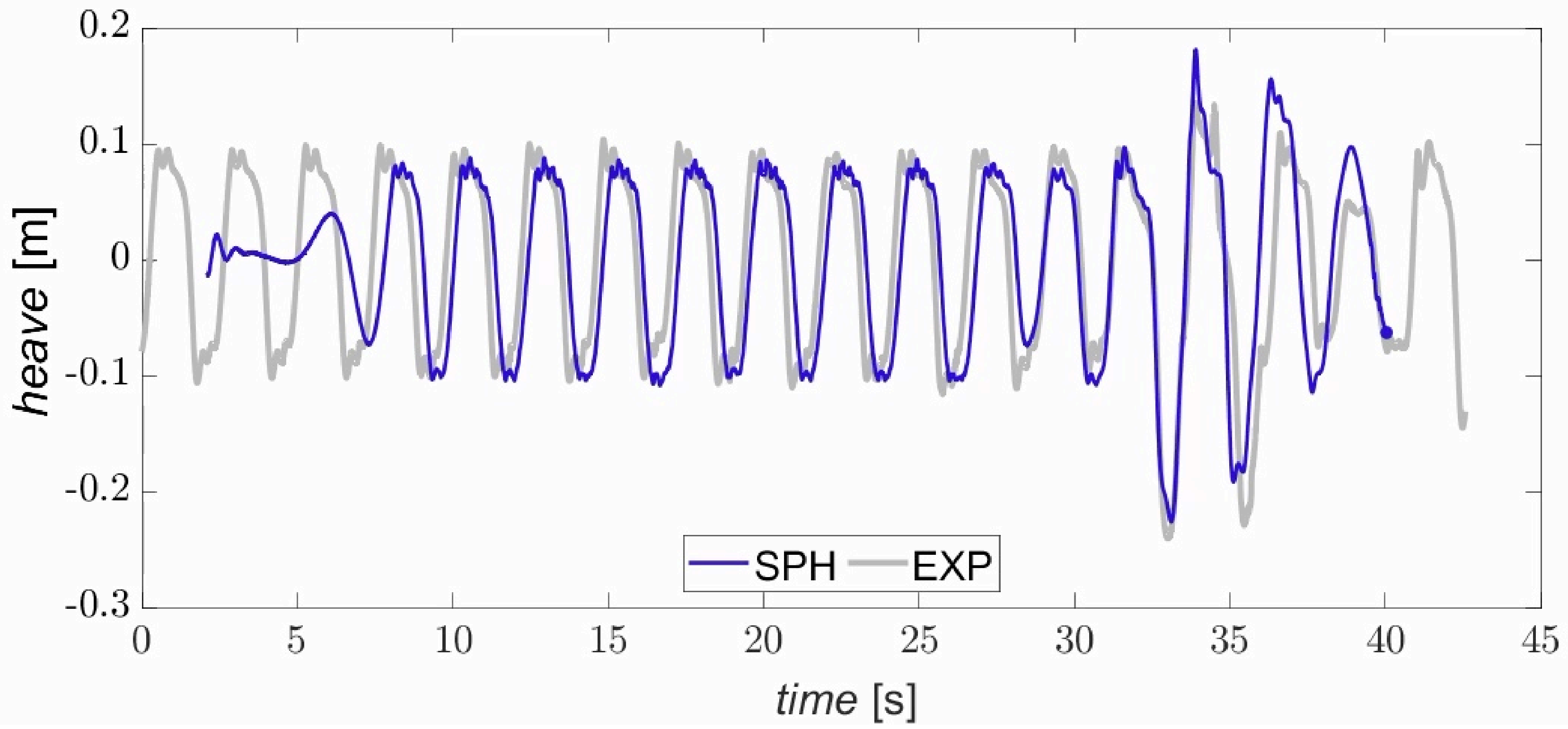
Focused wave simulation using a piston-type wavemaker





Detail of the PTO system modeled using Chrono





Tagliafierro et al., 2022, **APEN**

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WAVE ENERGY

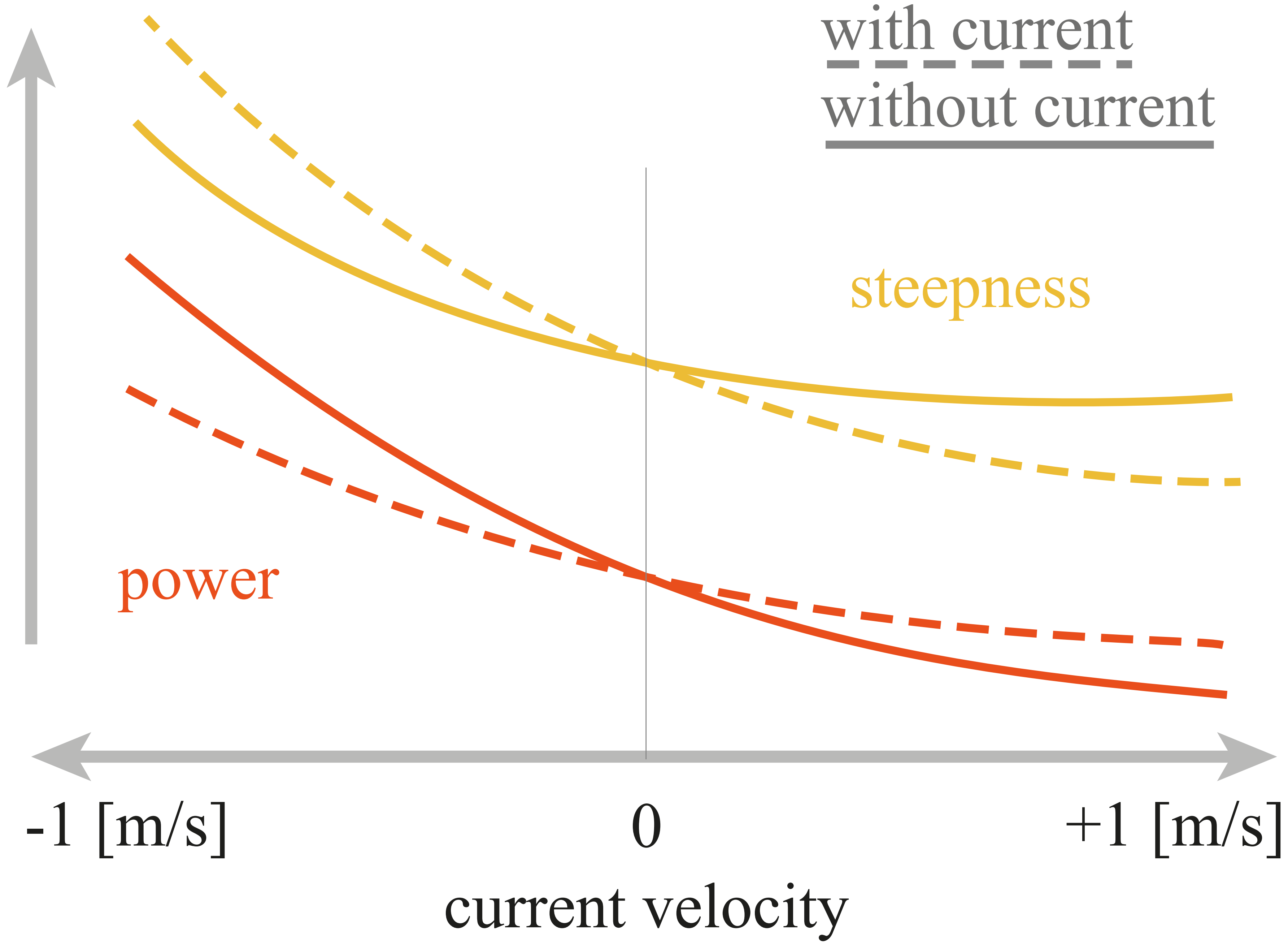
UUWEC: Waves and current effects

OPERATIONAL CONDITIONS

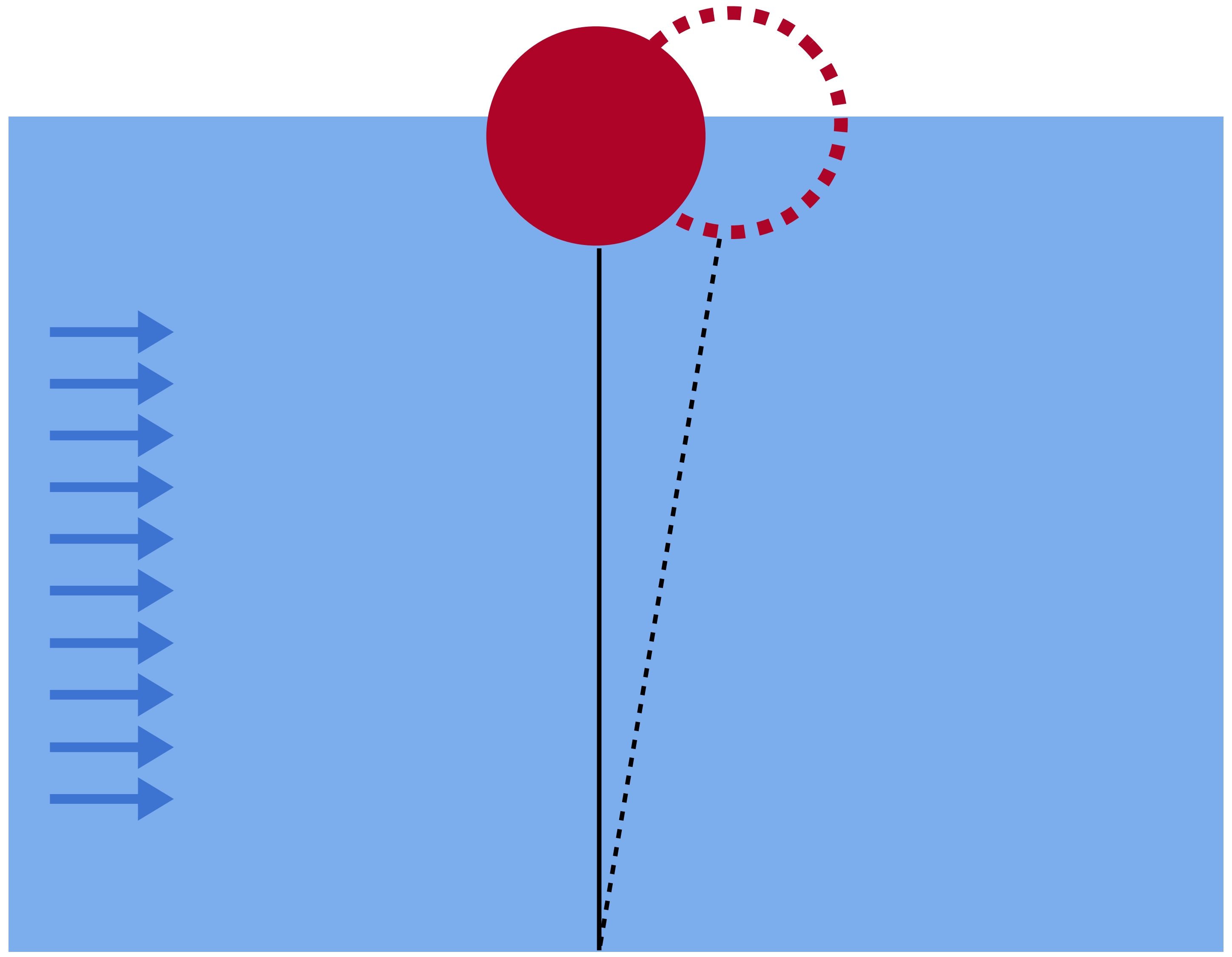
Wave and currents coexistence: likely load combination foreseen in design standards for offshore structures

DNV

What is current doing?



Both have effects!



Modifying the wave field: different wavelength, hence steepness and mean energy flux

Changing the hydrodynamic behavior of a floating body: shifted equilibrium position

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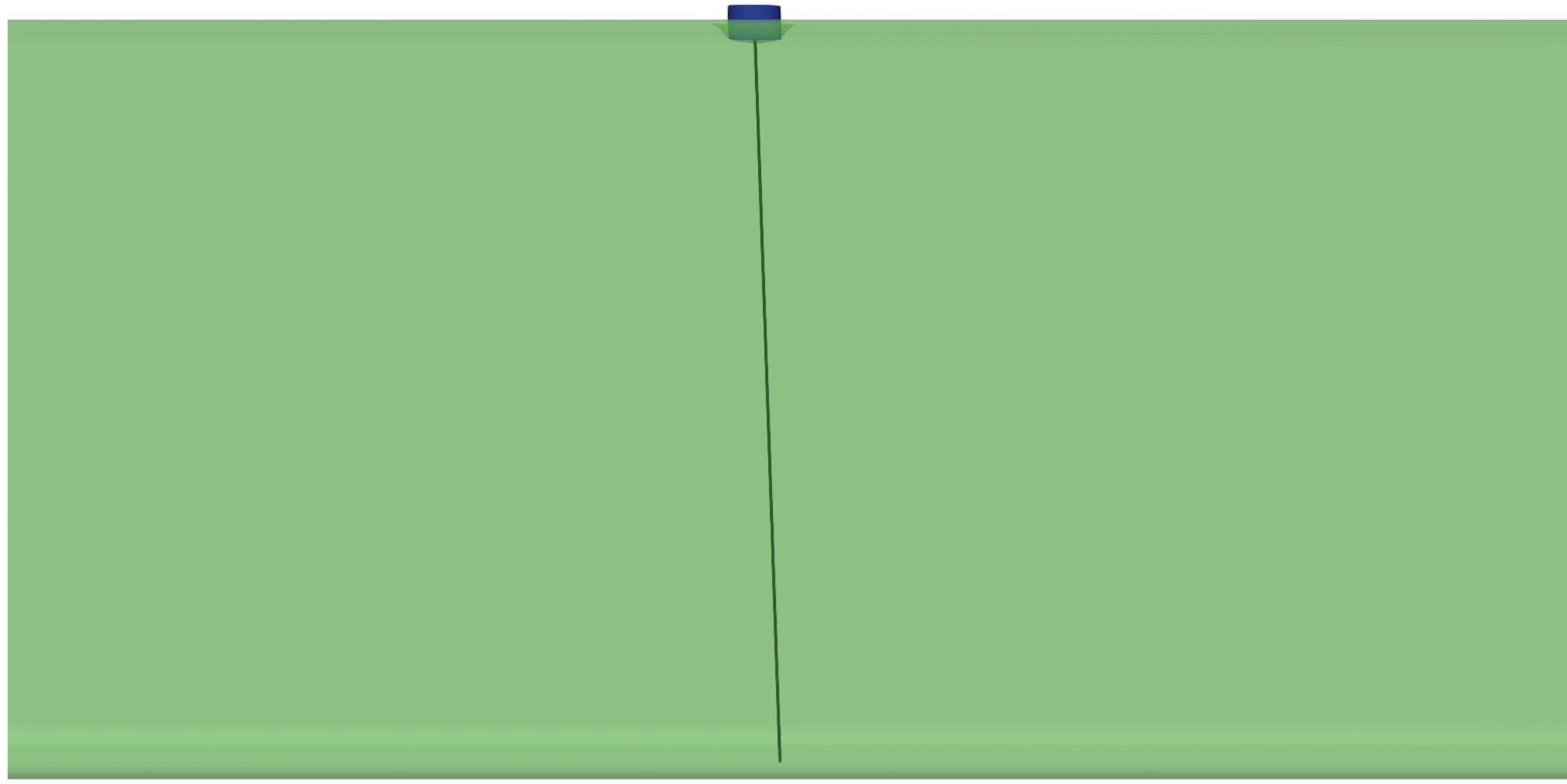
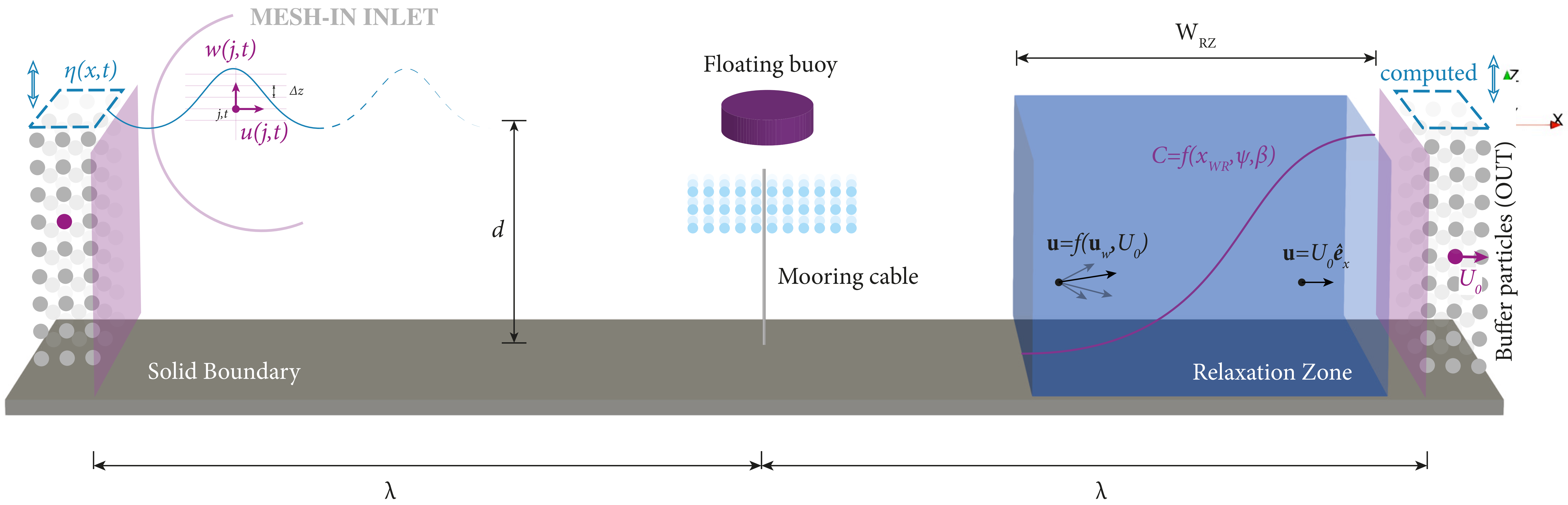
WAVE ENERGY UUWEC: Numerical Setup

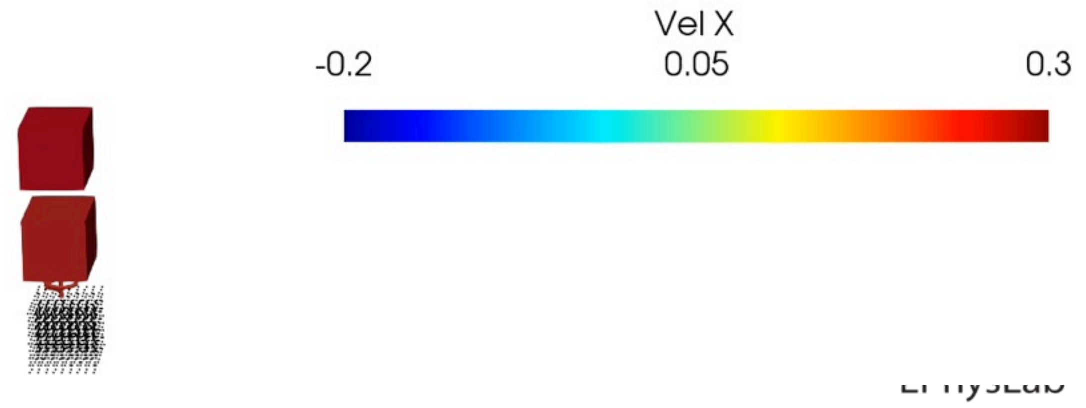


OPERATIONAL CONDITIONS

Open boundaries domain to investigate the current influence, using the same WEC design previously validated:

- same wave conditions and different current velocities

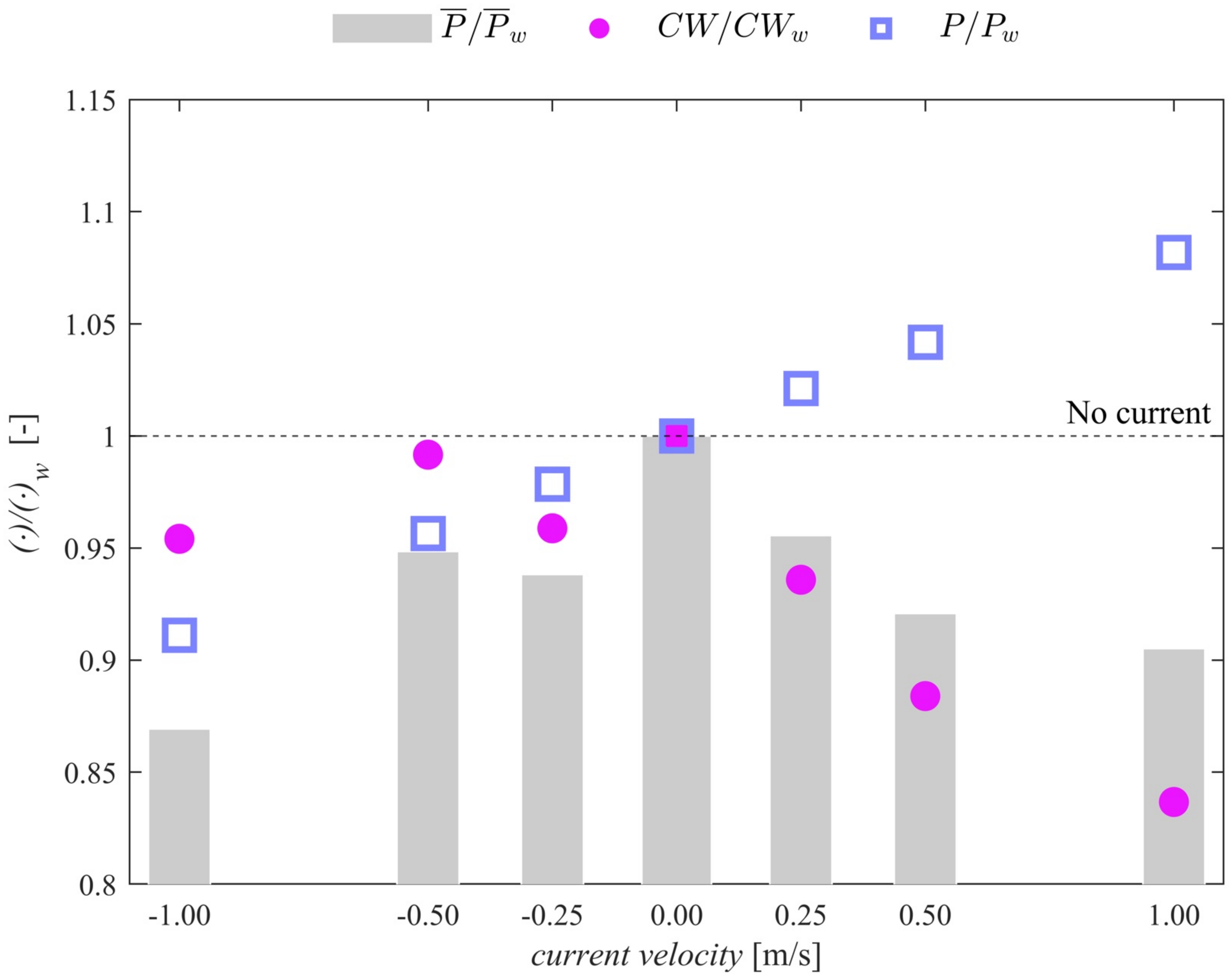


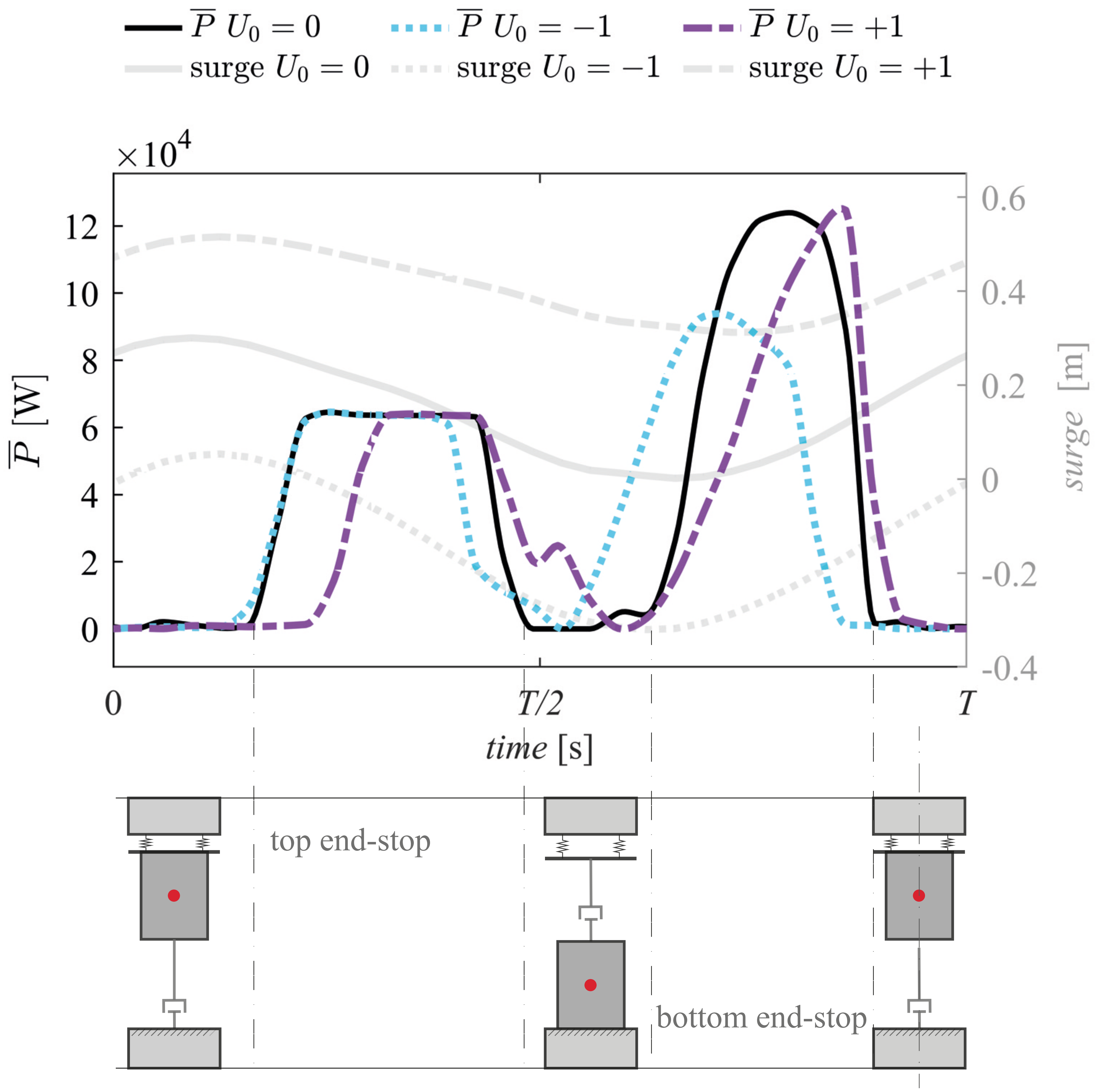


WAVE ENERGY UUWEC: Power output

$\overline{P}$ power output of the device
P available wave power
$CW = \overline{P}/P$ capture width

Normalised with respect to the quantities in absence of current





WAVE ENERGY

UUWEC: Power output

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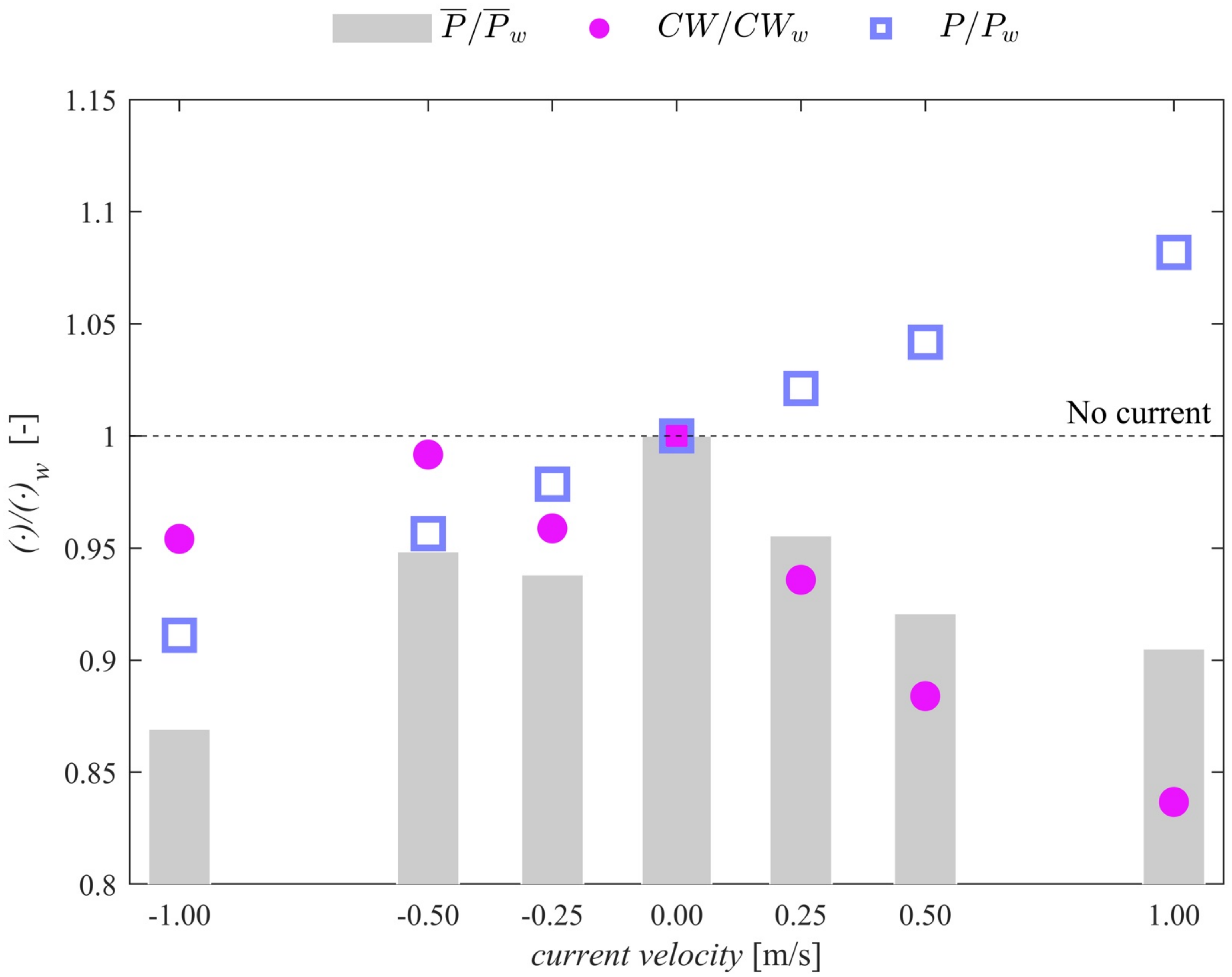
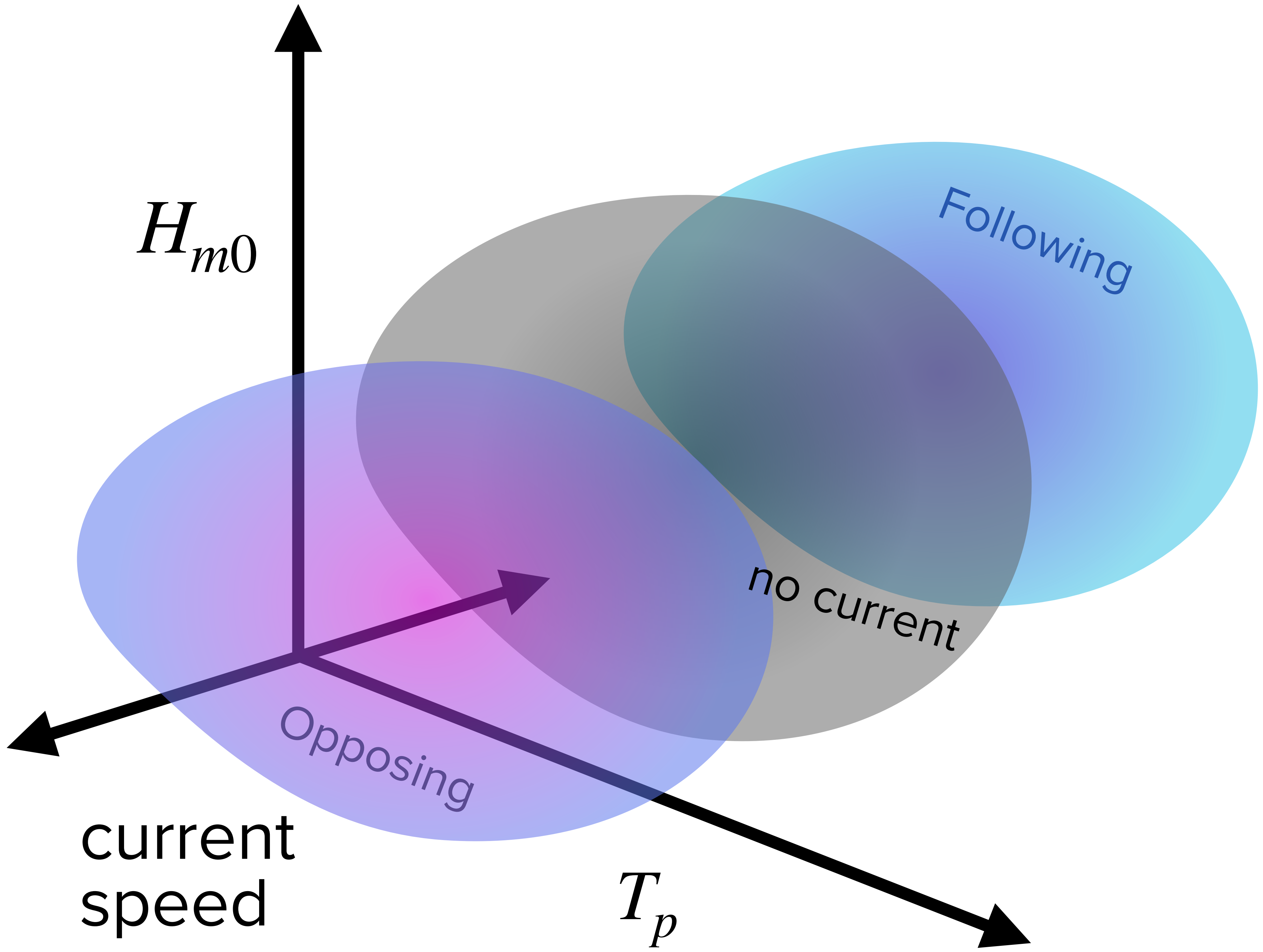


NONLINEAR RESPONSE

MORE AVAILABLE POWER $\neq$ MORE POWER PRODUCED

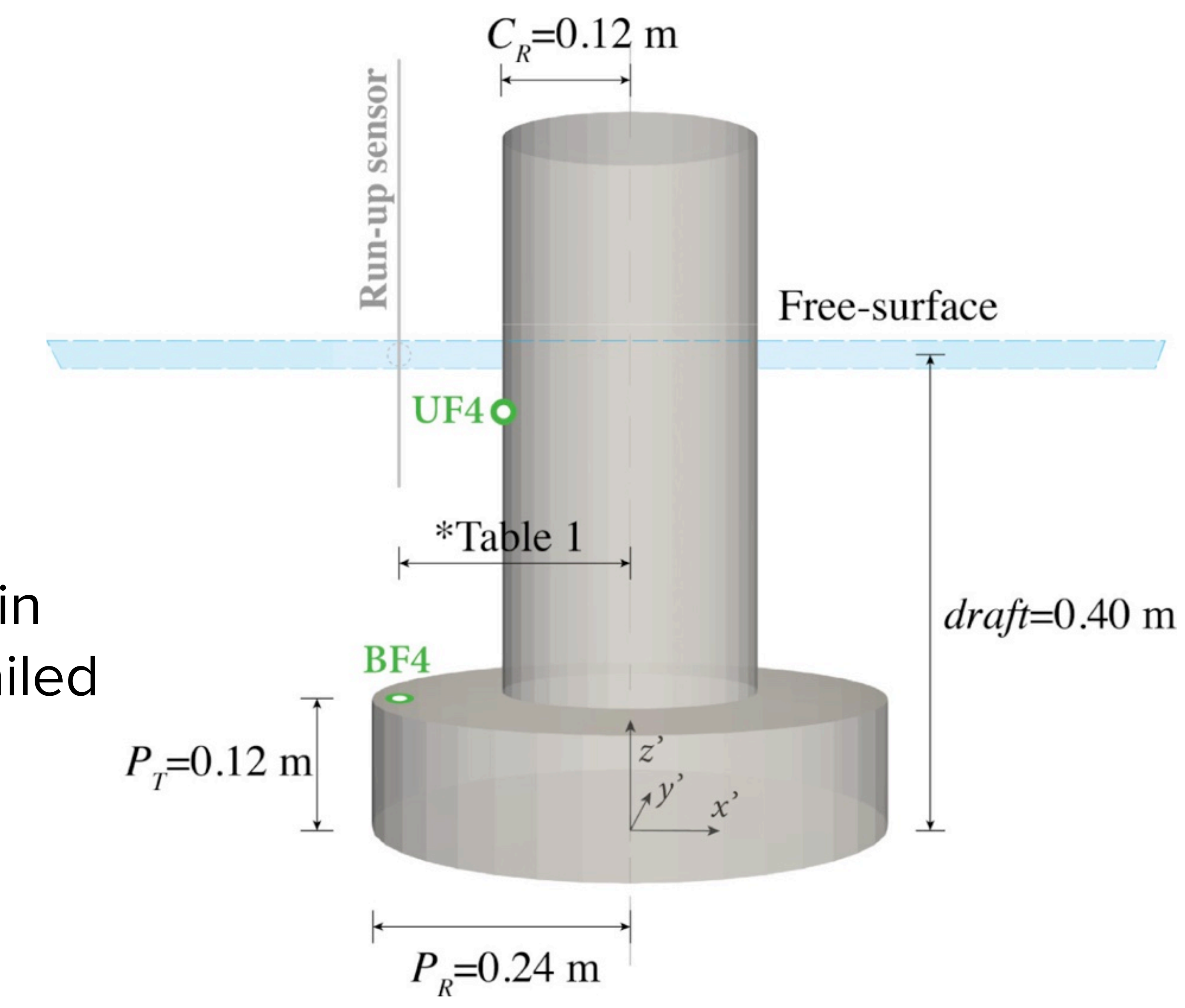


Reconsider the validity of power matrix when evaluating the power output of the device in presence of current

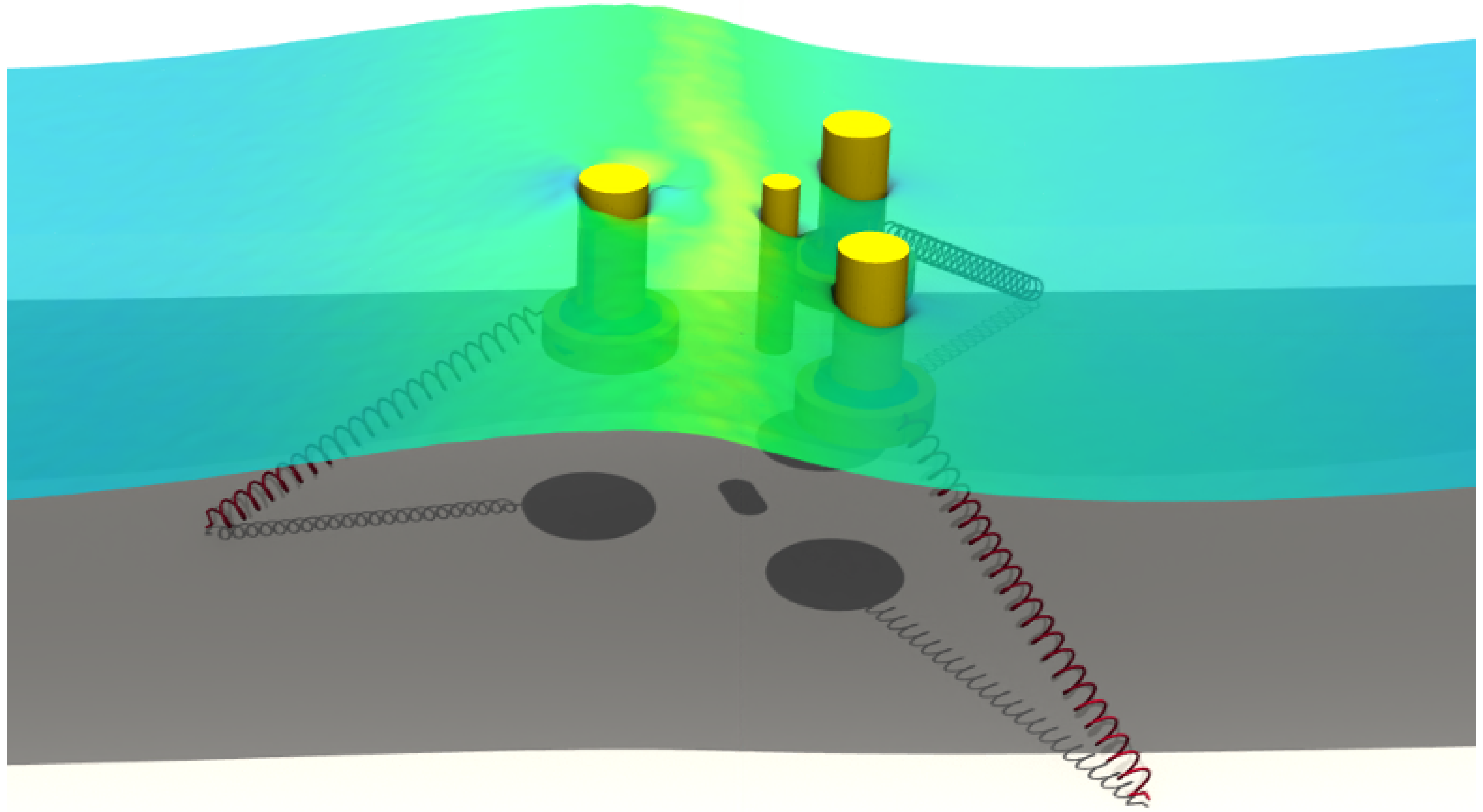
WIND ENERGY

Only recently DualSPHysics has been applied to FOWTs simulations, differently from WECs, for which it is a mature framework.

Here we show the hydrodynamic validation of a semi-submersible platform for Floating Offshore Wind Turbines (FOWTs)



Configurations the physical model included in the OC6 Phase Ib validation campaign. Detailed view of a single pontoon.



Tagliafierro, B., Karimirad, M., Altomare, C., Göteman, M., Martínez-Estévez, I., Capasso, S., Domínguez, J. M., Viccione, G., Gómez-Gesteira, M., & Crespo, A. J. C. (2023). *Numerical validations and investigation of a semi-submersible floating offshore wind turbine platform interacting with ocean waves using an SPH framework*. Applied Ocean Research, 141, 103757. https://doi.org/10.1016/j.apor.2023.103757

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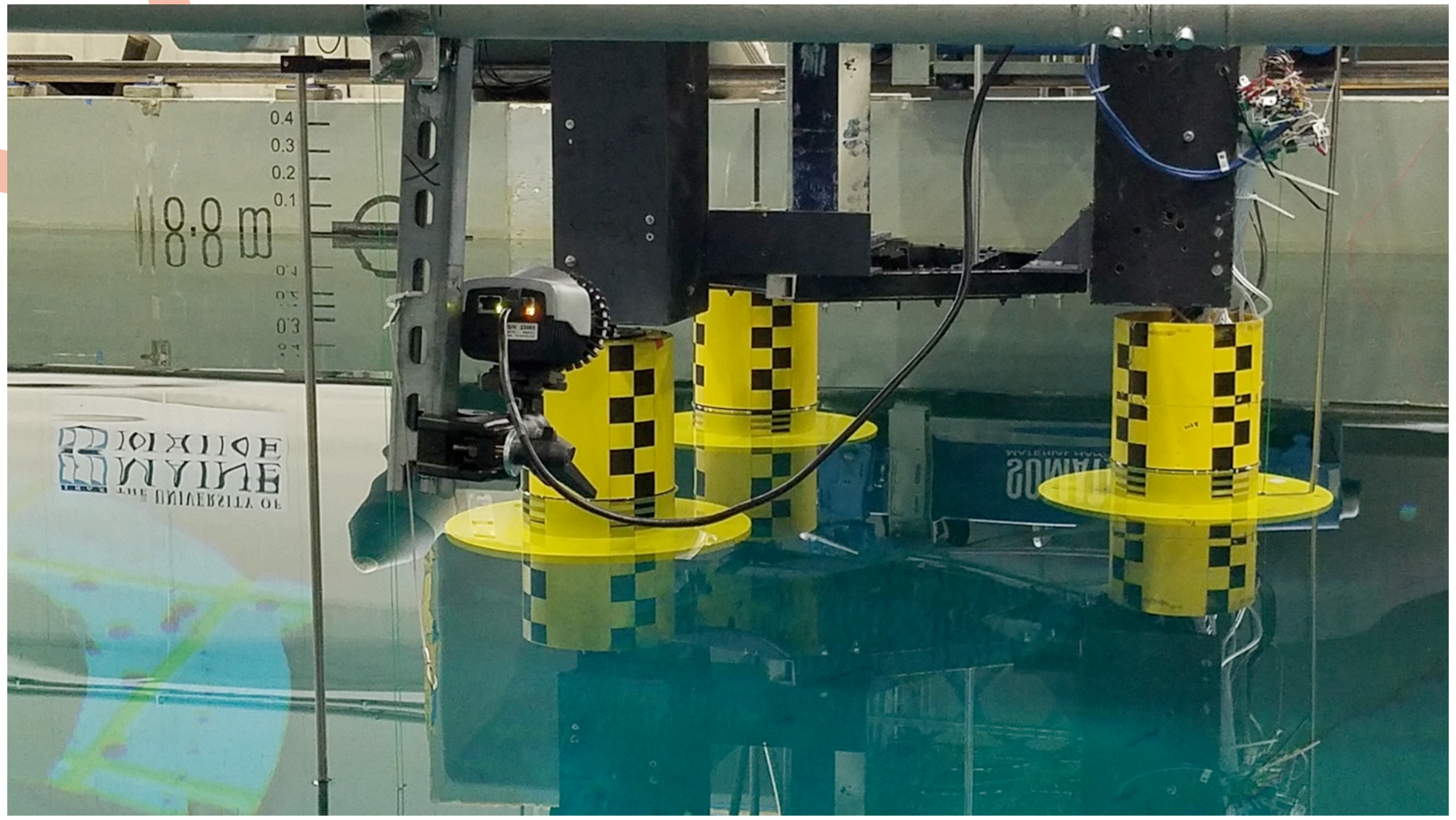
WIND ENERGY

DeepCWind: OC6 Project

Phase I of the OC6 project is focused on examining **why** offshore wind design tools underpredict the response (loads/motion) of the OC5-DeepCwind semisubmersible at its surge and pitch natural frequencies.

PHASE 1A

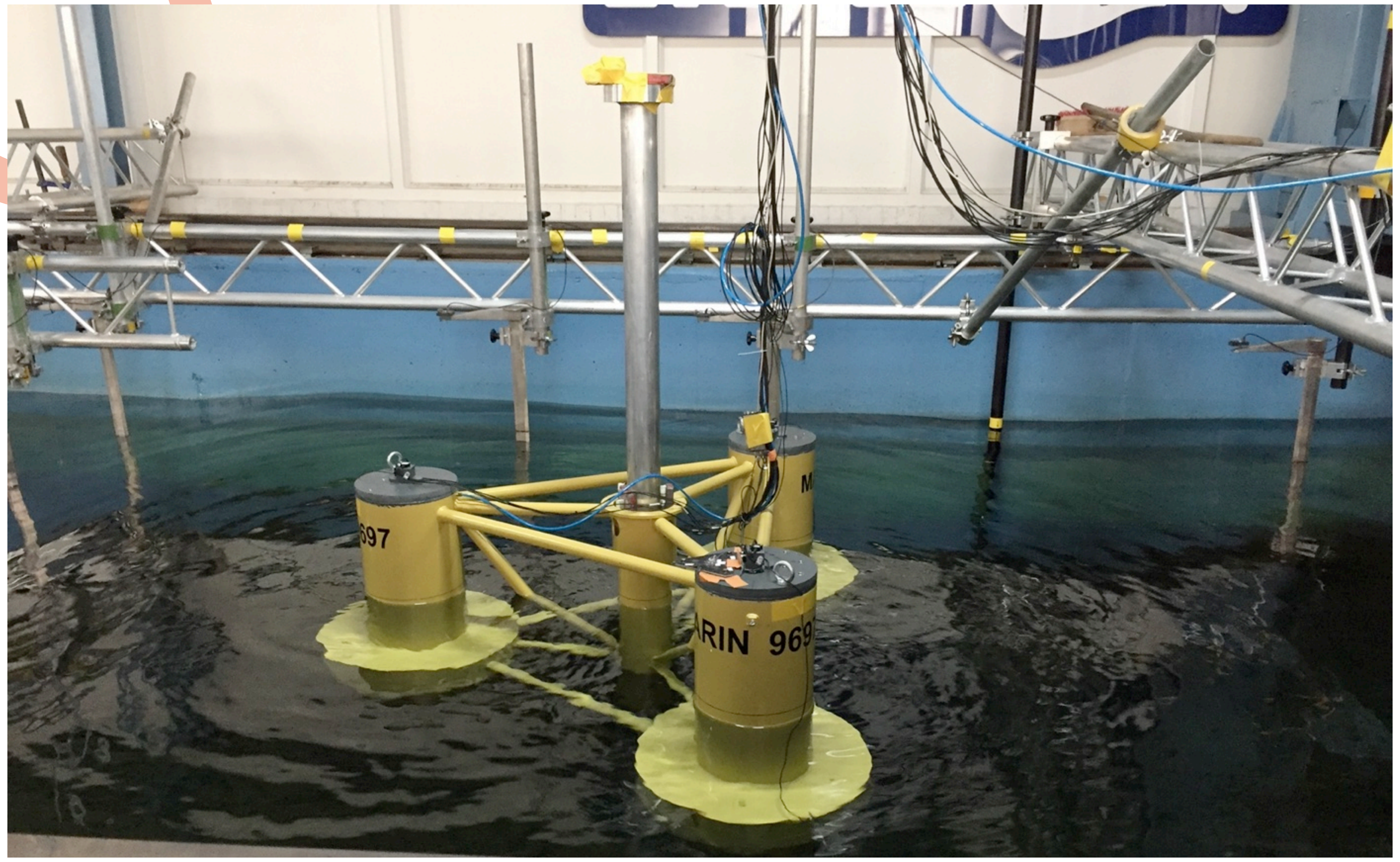
Hydrodynamic loads validation



Fixed simplified structure without central tower

PHASE 1B

free-decay motion validation

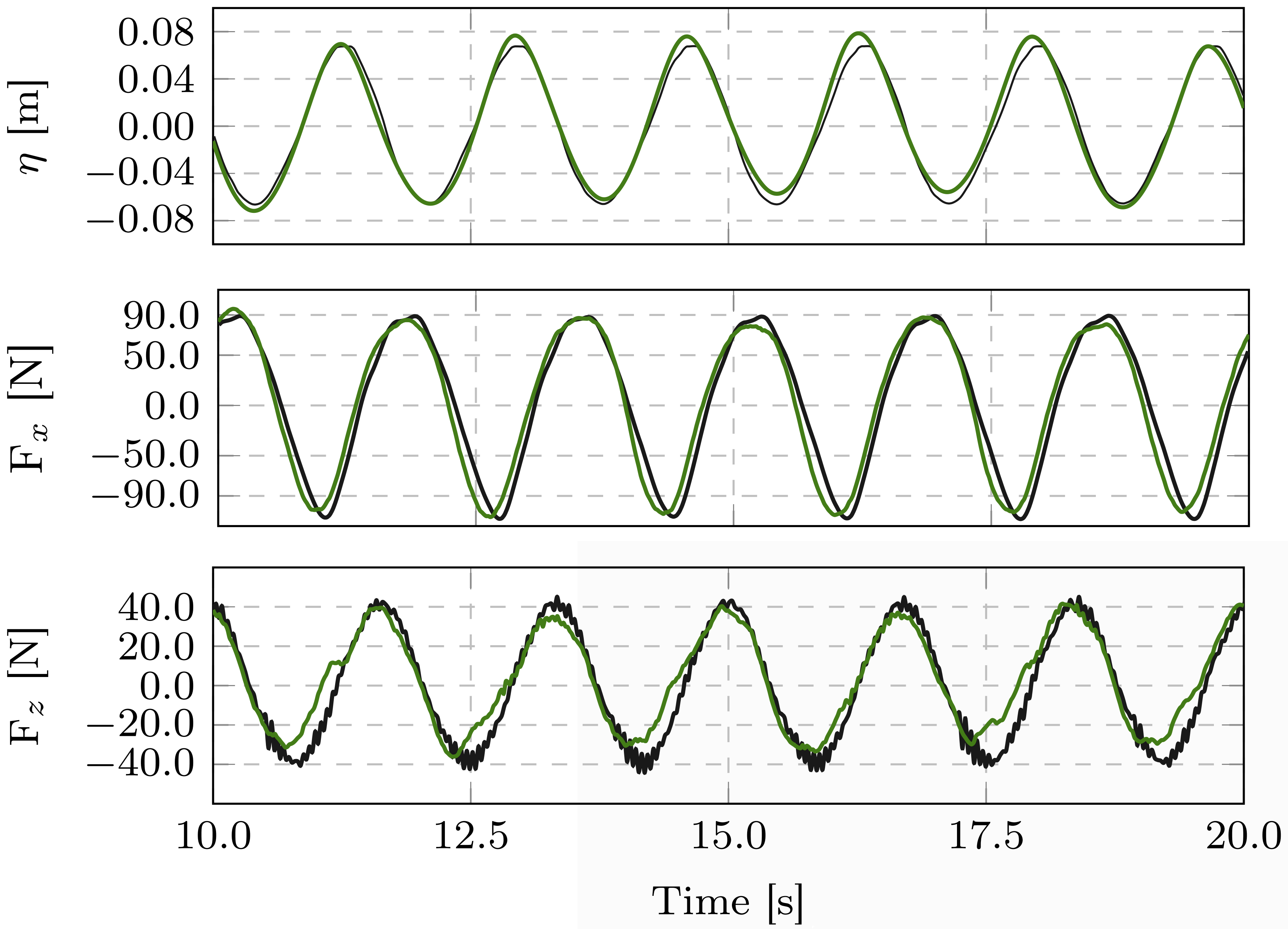


Realistic configuration of the platform allowing 1 DOF at time

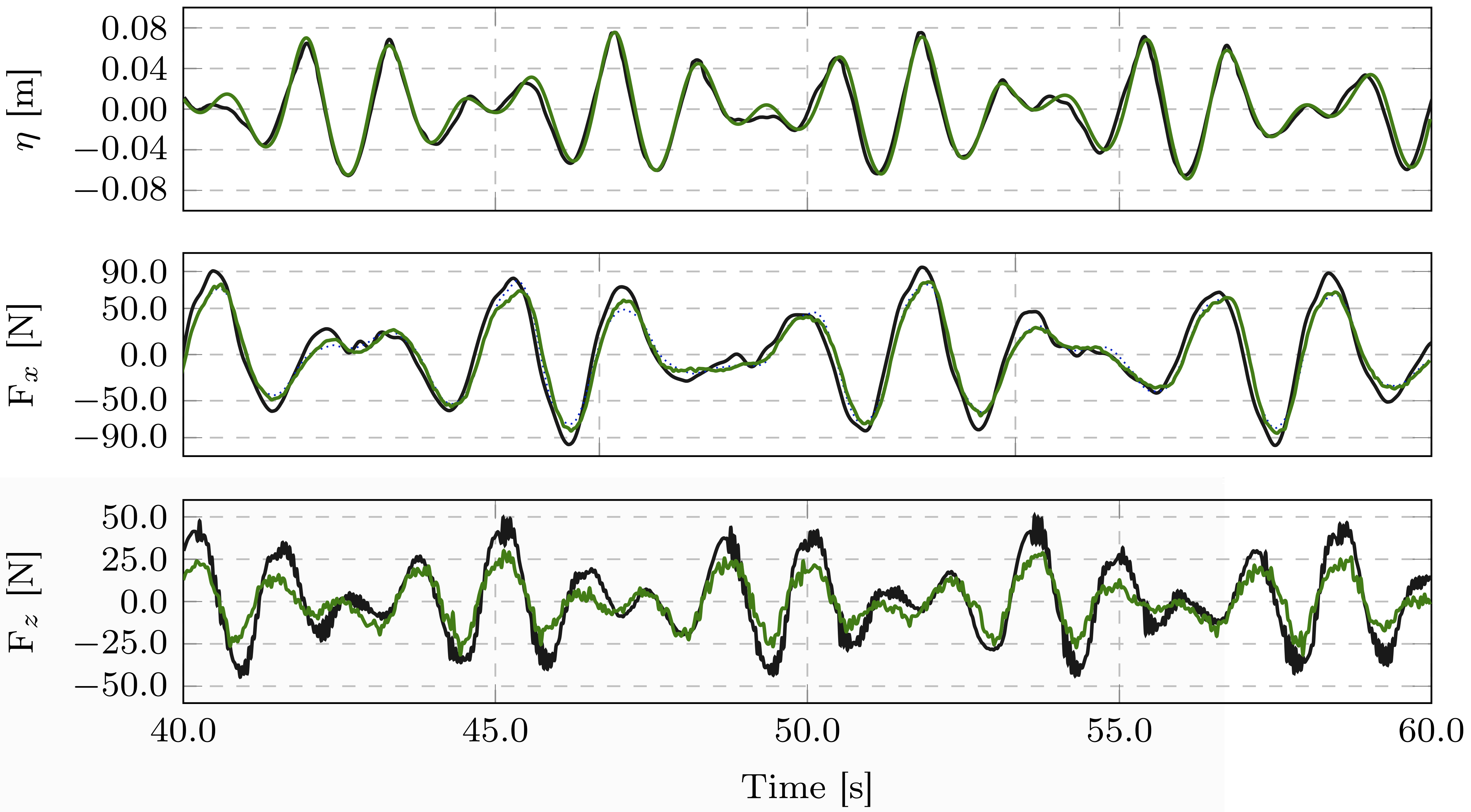
WIND ENERGY

DeepCWind: OC6 Phase 1A

Regular waves



Bichromatic waves



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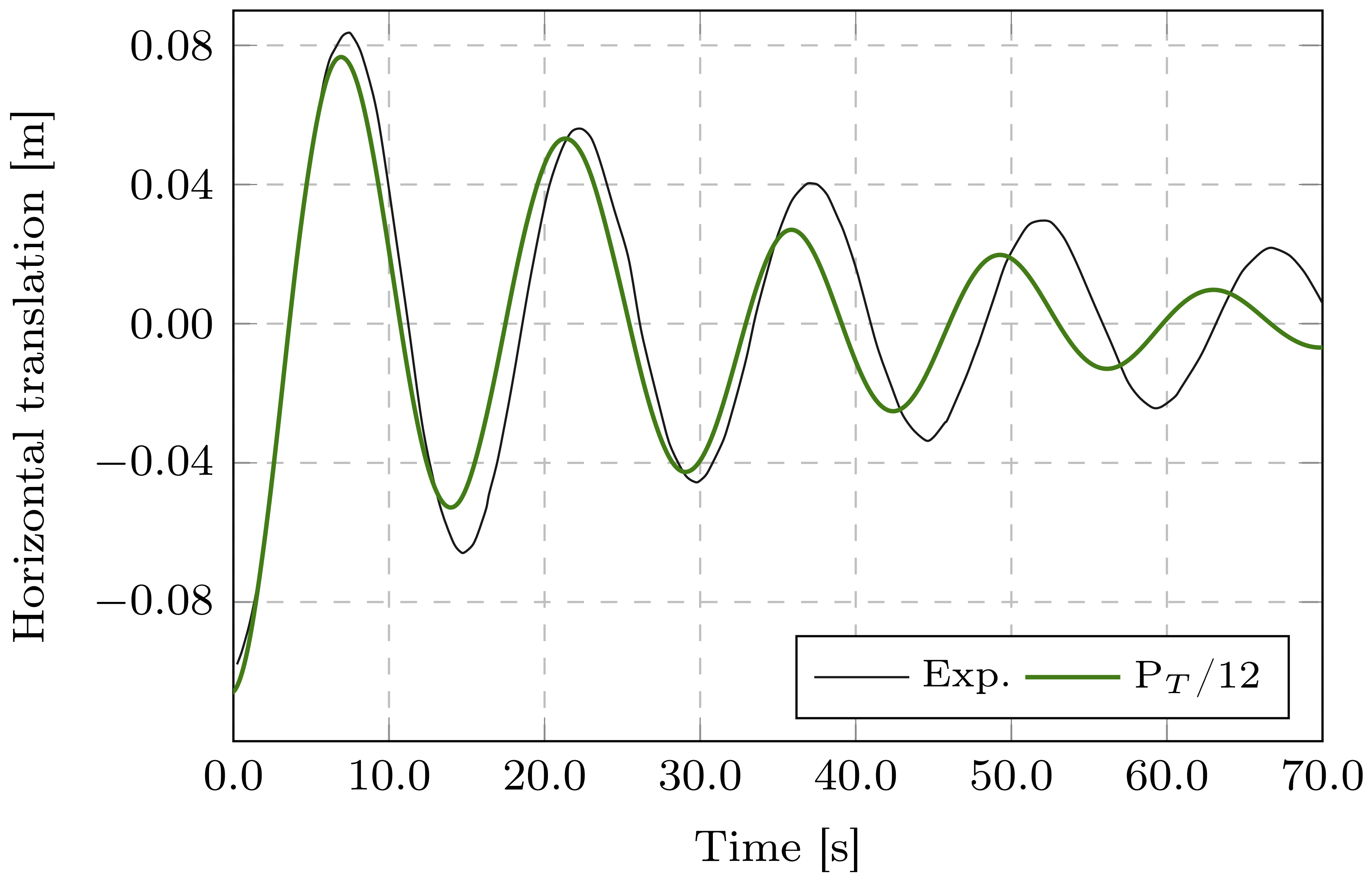
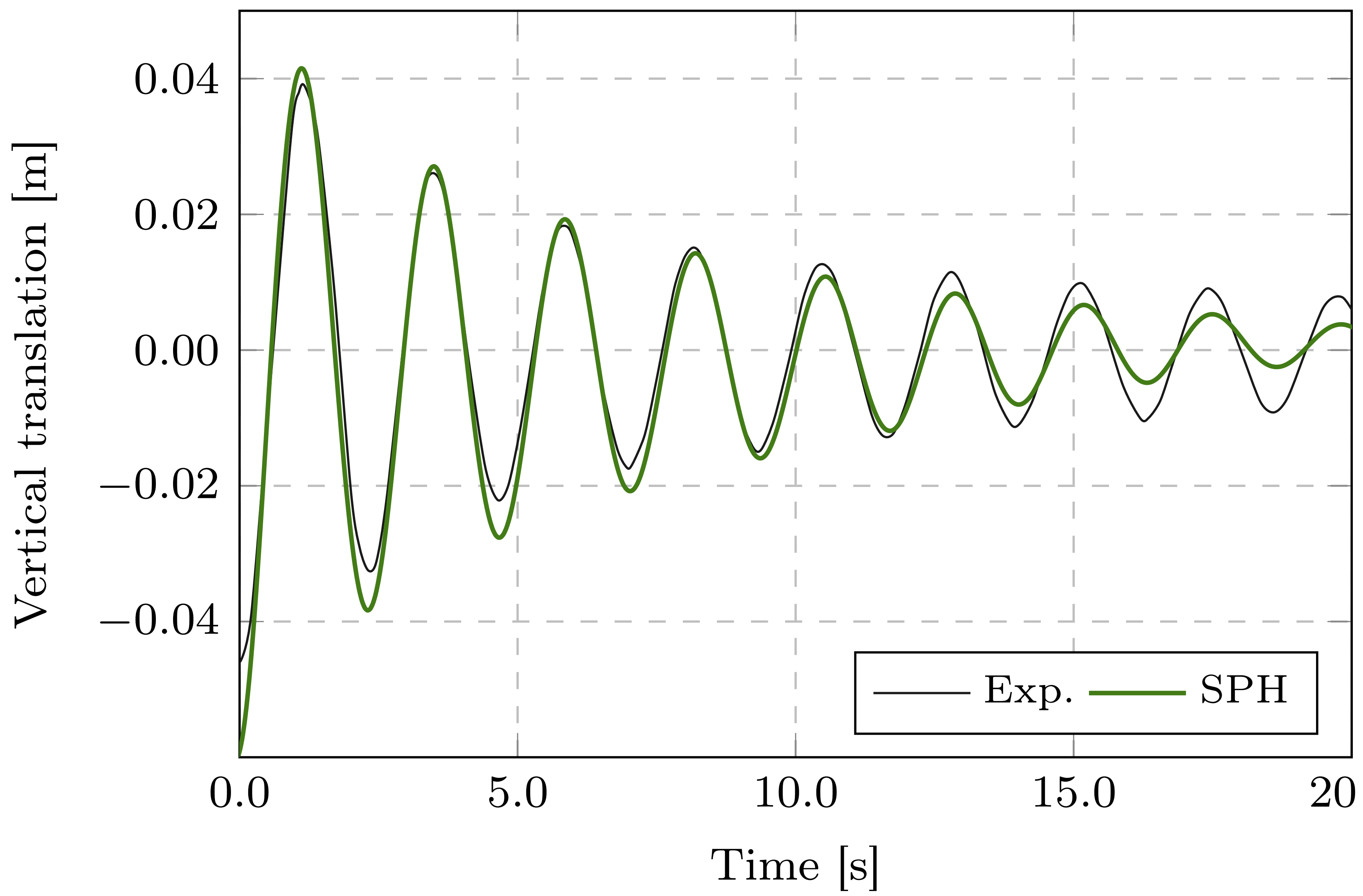
WIND ENERGY

DeepCWind: OC6 Phase 1B

SURGE



HEAVE



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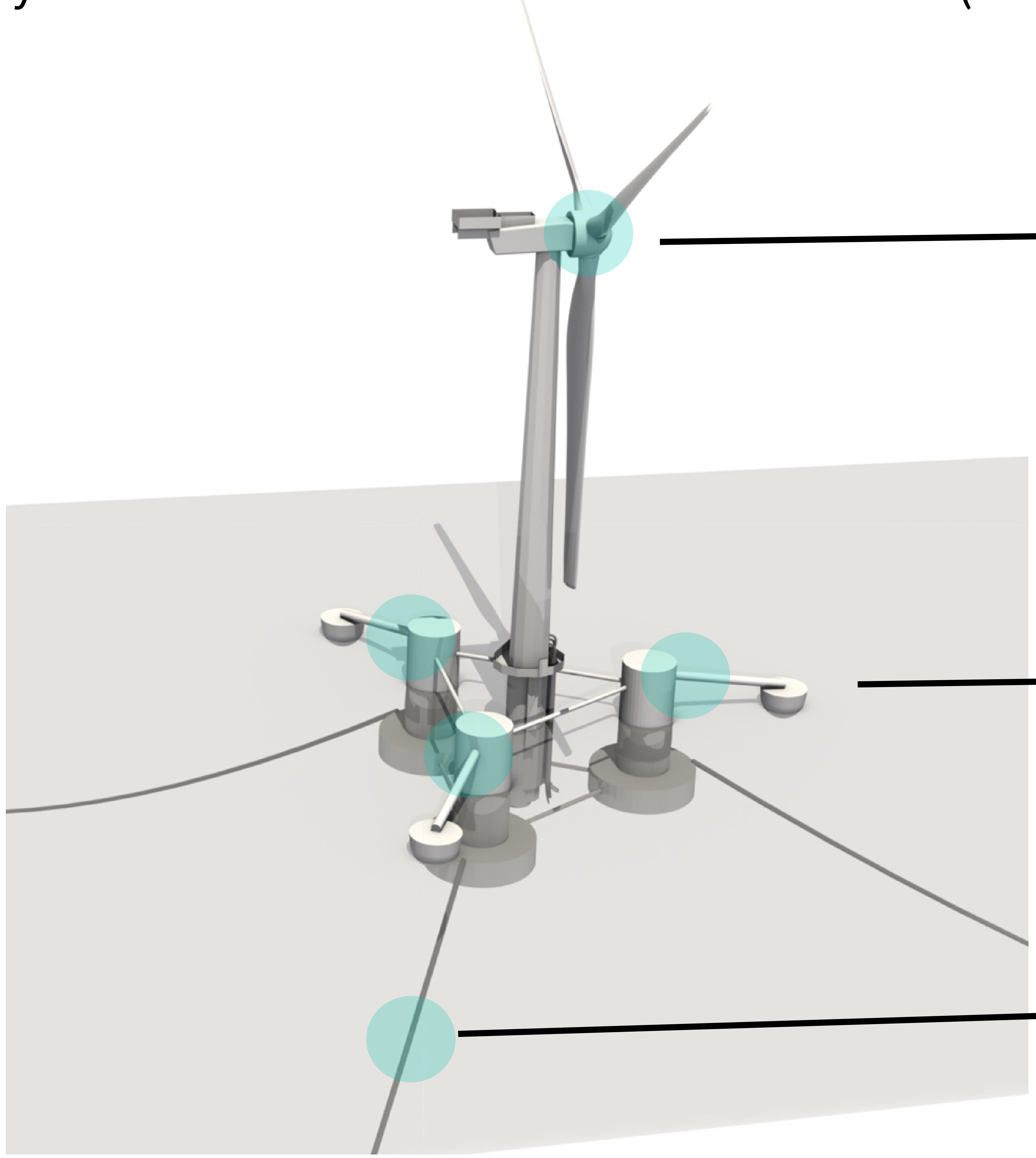
HYBRID PLATFORMS

A promising approach for harnessing multiple forms of ocean renewable energy involves integrating a hybrid system that combines a FOWT with WECs (similar to Wave-Star)



1. Revolute joint
2. Dampers (energy harvesting)
3. Imposed thrust and torque

PROJECT CHRONO

1. Revolute joints
2. Dampers (energy harvesting)

Catenary lines MoorDyn+

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FOWT and WECs under regular waves - using Chrono 8.0

CONCLUSIONS

CONCLUSIONS

CFD can help unveil nonlinear effects, not only with extreme waves, but whenever the combination of flow field and system characteristics requires high-fidelity modeling

- SPH remains a top-tier method for focused waves, wave breaking, overtopping
- Wave-current interaction poses unexpected challenges in performance evaluation of WECs

Dualsphysics is a reliable engineering tool in this sense, relying on a robust SPH core solver and external libraries to represent key features of ORE devices

- Computational effort becoming a secondary issue
- It is able to simulate highly dynamics devices (WECs) and very stable platforms (FOWts) (also simultaneously!)

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THANK YOU!
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